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The Grasses of Virginia

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Blacksburg, VA 24061-0331



The group of wildflowers called grasses cover vast areas of the earth. Ten of the fifteen major crops are grasses. The Bible says, "All flesh is grass" and truly it is so for all animals including humans are dependent upon these grasses and other higher plants. The tremendous usage of cereals, wheat, oats, barley, rye, corn, sorghum, rice and millet, sugar from sugar cane and in the Far East, bamboo for everything from food to construction material is an indication of man's dependence on grasses.

Grass plants are singularly easy to distinguish from other plants because of their 2-ranked bladelike leaves. They may be confused with sedges but careful study of the plants should lead to easy separation since sedges have 3-ranked leaves and solid stems while grasses do not.

An idealized grass plant is shown in Figure 1. It is made up of a fibrous root system, a jointed stem, flat narrow leaves borne on the stem in two ranks, one at each node, and a terminal inflorescence made up of few to many spikelets. The aboveground part of the plant is called the culm. A typical inflorescence is shown in Figure 2. The spikelet is a reduced, modified shoot made up of a stem (rachilla), reduced leaves (bracts) at each node, and secondary reduced shoots (flowers) in the axils of the bracts. Bracts of the lowest pair on the rachilla do not have secondary reduced shoots and are known as glumes. The uppermost bract on the secondary shoot is the palea which is partially enclosed by a bract called the lemma. The flower consisting of stamens and a pistil occurs in the axil of the palea. The grass fruit (caryopsis) may be free from the lemma and palea or permanently enclosed by them.

This paper on the grasses of Virginia is a contribution to the Flora of Virginia which has been in preparation for a number of years. This flora is to be for Virginia what the Flora of West Virginia and the Flora of the Carolinas are for West Virginia and North and South Carolina, an assemblage of information including keys and descriptions about the plants found in the area.

The grasses presented here are those contained in publications by Massey (1961) and Harvill *et al.* (1986). The keys have been developed from Core *et al.* (1944), Hitchcock and Chase (1951), and Roane (1986). Descriptions of genera and species have been modified from Bowden (1959), Core *et al.* (1944), Hitchcock and Chase (1951), Bothmer and Jacobsen (1985) and Gould and Shaw (1983). Common names are found in Blomquist (1948), Hitchcock and Chase (1951), Gould and Shaw (1983), Brown (1979), Knobel (1980), and Terrell (1977). For species distribution by county and city, see Harvill *et al.* (1986).

The helpful comments and suggestions of and assistance in proofreading by my husband, Curtis W. Roane, is gratefully acknowledged.

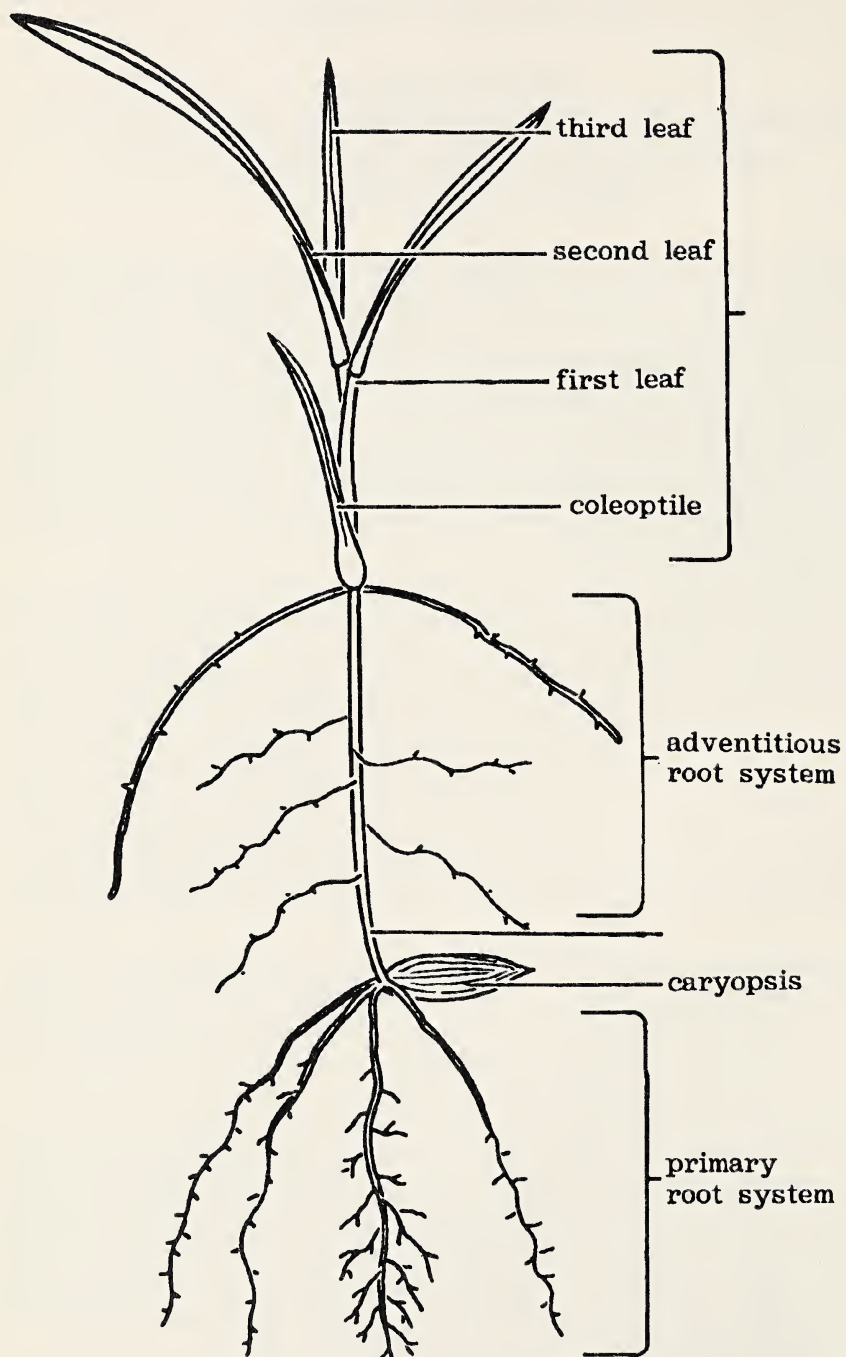


FIGURE 1. A typical grass plant. Drawing by J. D. Eisenback

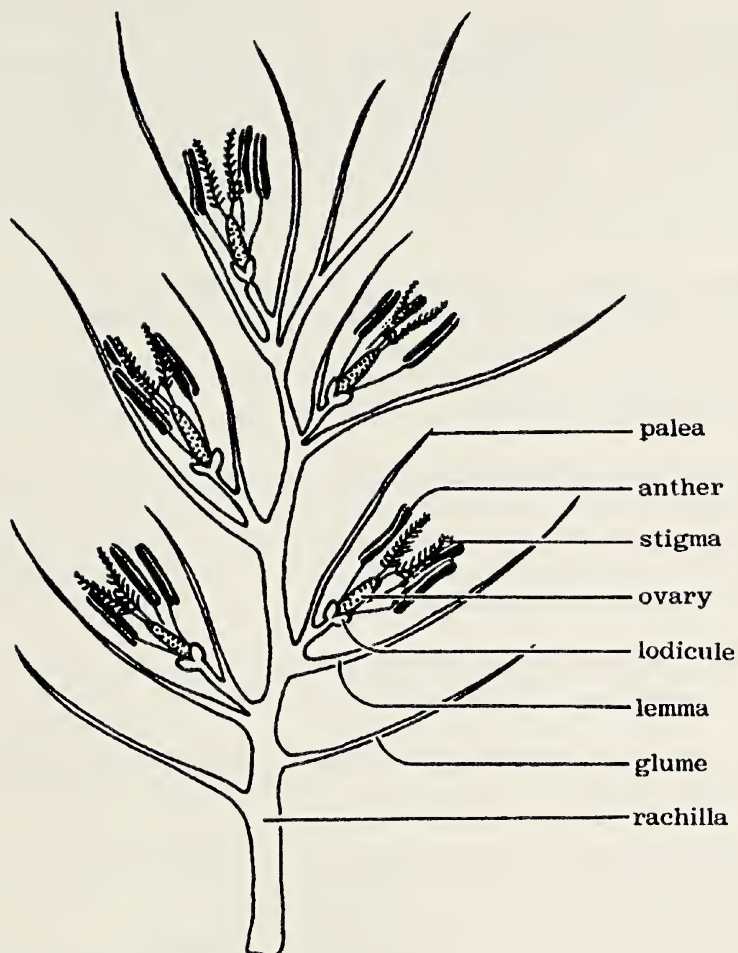


FIGURE 2. A typical grass inflorescence. Drawing by J. D. Eisenback.

KEY TO GENERA

1. Spikelets embedded in the joints of the rachis *Tripsacum*
- 1'. Spikelets not embedded in the rachis 2
2. Plants woody, culms perennial 3
- 2'. Plants herbaceous, culms annual 4
(plants may be perennial from below ground)
3. Culm terete; sheaths persistent *Arundinaria*
- 3'. Culm more or less flattened on one side; sheaths
nearly deciduous *Phyllostachys*

4.	Spikelets with one functional flower	5
4'.	Spikelets with 2 or more functional flowers	27
5.	Spikelets single	6
5'.	Spikelets in pairs	19
6.	Spikelets of two kinds	<i>Amphicarpum</i>
6'.	Spikelets all of one kind	7
7.	Spikelets subtended or surrounded by 1 to many distinct or more or less connate bristles forming an involucre	8
7'.	Spikelets not subtended by bristles	10
8.	Bristles persistent, spikelets deciduous	<i>Setaria</i>
8'.	Bristles falling at maturity	9
9.	Bristles not united at base, slender, often plumose	<i>Pennisetum</i>
9'.	Bristles united into a burlike involucre, bristles retroscly barbed	<i>Cenchrus</i>
10.	Glumes or sterile lemma awned	<i>Echinochloa</i>
10'.	Glumes and sterile lemma awnless	11
11.	Fruit cartilaginous-indurate, flexible	12
11'.	Fruit chartaceous-indurate, rigid	13
12.	Spikelets in more or less digitate racemes	<i>Digitaria</i>
12'.	Spikelets in panicles	<i>Leptoloma</i>
13.	Spikelets placed with the back of the fruit turned away from the rachis of the racemes, usually solitary	14
13'.	Spikelets placed with the back of the fruit turned toward the rachis of the spikelike racemes or pedicellate in panicles	16
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14'.	First glume present or wanting, not forming a ring-like callus below the spikelet	15
15.	First glume present; racemose along the main axis	<i>Brachiaria</i>
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16.	First glume typically wanting; spikelets plano-convex, subsessile in spikelike racemes	<i>Paspalum</i>
16'.	First glume present; spikelets usually in panicles	17
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- 17'. Second glume not inflated-saccate 18
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- 19'. Spikelets unlike, the sessile perfect, the pedicellate sterile . . 22
20. Spikelets surrounded by a copious tuft of hairs 21
- 20'. Spikelets not surrounded by tufts of hairs; racemes few . . *Microstegium*
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- 21'. Rachis breaking up into joints at maturity with the spikelets attached, one spikelet sessile, the other pedicellate *Erianthus*
22. Pedicel thickened, appressed to the thickened rachis joint or adnate to it; spikelets awnless, appressed to the rachis joint 23
- 22'. Pedicel not thickened, neither appressed nor adnate to the rachis joint; spikelets usually awned 24
23. Rachis thickened *Manisurus*
- 23'. Rachis slender *Eremochloa*
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- 24'. Blades narrow, elongate; annual or perennial 25
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- 28'. Spikelets subterete in x-section, unisexual; all plants monoecious 29
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- 38'. Spikelets with 1 or more modified florets above the perfect one 40
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- 54'. Lemma awnless or awned from the back 56
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seed adnate to the pericarp *Muhlenbergia*
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- 60'. Low or rather tall grasses, rarely more than 1.5 m tall . . . 62
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63. Plants dioecious, perennial; spikelets in narrow,
simple exserted panicles *Distichlis*
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panicle dense, spikelike *Cynosurus*
- 64'. Spikelets all alike in the same inflorescence 65
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66. Lemmas pubescent on nerves or callus, midnerve
usually exserted as awn or mucro 67

- 66'. Lemmas not pubescent on nerves or callus, awnless 68
67. Palea densely long ciliate on upper half *Triplasis*
- 67'. Palea sometimes villose but not long-cilliate on upper half . *Tridens*
68. Lemmas chartaceous; grain large, beaked at maturity
forcing lemma and palea open *Diarrhena*
- 68'. Lemmas membranaceous; if firm, neither large
nor beaked *Eragrostis*
69. Spikelets with 1 to 4 empty lemmas below the fertile
florets, nerves obscure, lemmas firm *Uniola*
- 69'. Spikelets with no empty lemmas below the fertile florets,
nerves usually prominent, lemmas membranaceous 70
70. Lemmas as broad as long, margins outspread, florets
horizontally spreading *Briza*
- 70'. Lemmas longer than broad, margins clasping palea,
florets not horizontally spreading 71
71. Callus of florets bearded; lemmas bifid at summit,
awned *Schizachne*
- 71'. Callus not bearded; lemmas not erose
(slightly in *Puccinellia*) 72
72. Lemmas keeled on the back 73
- 72'. Lemmas rounded on the back 75
73. Spikelets strongly compressed, crowded in 1-sided clusters
at the ends of the stiff, naked panicle branches *Dactylis*
- 73'. Spikelets not strongly compressed, not crowded in
1-sided clusters 74
74. Lemmas awned from a minutely bifid apex, spikelets large *Bromus*
- 74'. Lemmas awnless, spikelets small *Poa*
75. Glumes papery; upper florets sterile *Melica*
- 75'. Glumes not papery; upper florets like the others 76
76. Nerves of lemma parallel, not or slightly converging
at the summit 77
- 76'. Nerves of lemma converging toward the summit 78
77. Nerves prominent; plant usually rather tall, growing
in woods or fresh-water marshes *Glyceria*
- 77'. Nerves faint; plants low, growing in saline soil *Puccinellia*

78. Lemmas awned or awn-tipped from a minutely bifid apex . . . *Bromus*
 78'. Lemmas entire, pointed, awnless or awned from the tip . . . 80
79. Spikelets awned (awnless in a few perennial species);
 lemmas jointed *Festuca*
 79'. Spikelets awnless *Poa*
80. Florets 2, one perfect, one staminate 81
 80'. Florets 2 or more, all alike except the upper reduced ones . . . 82
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 82'. Articulation above the glumes 83
83. Lemmas bifid at apex, awned or mucronate between
 the lobes; spikelets several-flowered *Danthonia*
 83'. Lemmas toothed, but not bifid and awned or mucronate
 between the lobes 84
84. Glumes 2 to 3.5 cm long, 7- to 9-nerved; spikelets 2-flowered
 or with a rudimentary third floret, pendulous *Avena*
 84'. Glumes not more than 1 cm. long, 1- to 5-nerved; spikelets
 not pendulous 85
85. Rachilla prolonged behind upper floret; lemmas truncate
 and erose-dentate at summit *Deschampsia*
 85'. Rachilla not prolonged, lemmas tapering into
 2 slender teeth *Aira*
86. Spikelets solitary at each node of rachis 87
 86'. Spikelets more than one at each node of rachis 90
87. Spikelets sunken in rachis, 1-flowered *Parapholis*
 87'. Spikelets not sunken in rachis, 2- to several-flowered 88
88. Spikelets placed edgewise to rachis *Lolium*
 88'. Spikelets placed flatwise to rachis 89
89. Plants annual *Aegilops*
 89'. Plants perennial *Agropyron*
90. Spikelets three at each node, 1-flowered, the latter
 pair pediceled and usually reduced to awns *Hordeum*
 90'. Spikelets two or more, sometimes solitary, at each node
 of rachis, 2- to 6-flowered 91

91. Glumes wanting or reduced to two short bristles;
 spikelets horizontally spreading or ascending *Hystrix*
 91'. Glumes usually equalling florets; spikelets appressed
 or ascending *Elymus*

SPECIES DESCRIPTIONS

Aegilops L. Goatgrass

Annual; blades flat; culms unbranched; spikes terminal; spikelets 2- to 5-flowered, solitary, turgid or cylindric, placed flatwise at each joint of rachis; joints thickened at summit; spike usually disarticulating near base at maturity, falling entire or disarticulating between spikelets.

Aegilops cylindrica Host. Jointed goatgrass.

Culms erect, branching at base, 40-60 cm tall; blades 2-3 mm wide; spike cylindric, 5-10 cm long; internodes of rachis 6-8 mm long; spikelets 8-10 mm long, glabrous to hispid; glume, several-nerved, keeled at 1 side, the keel extending into an awn, the main nerve of the other side extending into a short tooth; lemmas mucronate, those of the uppermost spikelet, awned like the glume; awns very scabrous, those of the upper spikelets about 5 cm long, those of the lower spikelets progressively shorter. Weed in wheatfields and waste places in Buckingham, Campbell, Clarke, Giles, Montgomery, Nelson, Page, Pulaski, Rockingham, Russell and Tazewell Counties. Hitchcock noted that *A. ovata* L. is a weed in California and Virginia. The spike disarticulates in *A. cylindrica* but not in *A. ovata*.

Agropyron Gaertn. Wheatgrass

Perennial; culms unbranched and usually erect; spikes terminal; spikelets several-flowered, solitary, in alternate notches of zigzag rachis; glumes equal, shorter than first lemma, acute or awned; lemmas convex, acute or awned; palea about as long as lemma.

1. Leaves mostly 6-10 mm wide; creeping rhizomes present . . . *A. repens*
 1'. Leaves mostly 2-4 mm wide; rhizomes absent *A. trachycaulum*

Agropyron repens (L.) Beauv. Quackgrass. Couchgrass. Couch. Twitch.
 Witchgrass.

Green or glaucous; culms erect or curved at base, 50-100 cm tall, sometimes taller, with creeping yellowish rhizomes; sheaths of the innovations often pubescent; blades relatively thin, flat, usually sparsely pilose on upper surface, mostly 6-10 mm wide; spike 5-15 cm long, the rachis scabrous in the angles; spikelets mostly 4- to 6-flowered, 1-1.5 cm long, the rachilla glabrous or puberulous; glumes 3- to 7-nerved, awnpointed; lemmas mostly 8-10 mm long, the awn from less than 1 mm to as long as the lemma; palea obtuse, nearly as long as the lemma, scabrous on the keels. Obnoxious weed of waste places, meadows and pastures; common in mountains and Piedmont. Introduced from Eurasia.

Agropyron trachycaulum (Link) Malte. Slender wheatgrass. Awned wheatgrass.

Green or glaucous, without creeping rhizomes; culms erect, tufted, 50-100 cm tall; sheaths glabrous or rarely pubescent; blades mostly 2-4 mm wide; spike slender, 10-25 cm long, sometimes unilateral; spikelets from rather remote to closely imbricate; glumes and lemmas awnless or nearly so. Mountains of Alleghany, Augusta, Bath, Botetourt, Highland, Rockbridge, Rockingham and Smyth Counties. A northern species reaching its southern limit in our area, common in

the far west where it is cultivated extensively. It is one of the few native grasses of North America in cultivation.

Agrostis L. Bentgrass

Annual or usually perennial; culms ascending, erect or decumbent; spikes terminal; spikelets one-flowered, disarticulating above glumes; glumes equal or nearly so, acute, acuminate or awn-pointed, usually scabrous on keel; lemma obtuse, usually shorter than glumes, awnless or dorsally awned; palea usually shorter than lemma, may be obsolete.

1. Palea 2-nerved 2
- 1'. Palea obsolete or a minute nerveless scale 6
2. Glumes scabrous on keel and back; panicle contracted, lobed, the short branches densely verticillate *A. semiverticillata*
- 2'. Glumes scabrous on keel only; panicle open, or if contracted, not lobed nor with densely verticillate branches 3
3. Branches of panicle naked at base; ligule up to 2 mm long on culm *A. tenuis*
- 3'. Branches of panicle or some of them floriferous from base; ligule up to 6 mm long 4
4. Panicle contracted, branches appressed; long stolons . . . *A. palustris*
- 4'. Panicle open, branches ascending; no long stolons 5
5. Culms decumbent at base; rhizomes wanting *A. stolonifera*
- 5'. Culms erect; rhizomes developed *A. alba*
6. Plants annual, lemma with a slender flexuous, delicate awn *A. elliottiana*
- 6'. Plants perennial; lemmas awned or awnless, when present not much exerted 7
7. Panicle very diffuse, the capillary branches branching above the middle or toward the end 8
- 7'. Panicle open but not diffuse, the branching occurring at or below the middle 9
8. Spikelets 1.5-1.7 mm long, very densely clustered at ends of branchlets; lemma 1-1.2 mm long, scarcely longer than caryopsis *A. hiemalis*
- 8'. Spikelets 2-2.7 mm long, loosely arranged at the ends of branchlets; lemmas 1.5-1.7 mm long, distinctly longer than caryopsis *A. scabra*
9. Lemma awnless 10
- 9'. Lemma awned *A. borealis*
10. Spikelets mostly 2.2-2.7 mm long, not aggregate or but slightly so at ends of panicle branches *A. perennans*
- 10'. Spikelets mostly 2.7-3.5 mm long, aggregate towards ends of panicle branches *A. altissima*

Agrostis semiverticillata (Forsk.) C. Christ. Water bent.

Culms usually decumbent at base, sometimes with long creeping and rooting stolons; blades firm, mostly relatively short and broad, but in luxuriant specimens elongate; panicle contracted, 3-10 cm long, densely flowered, lobed, with short verticillate branches, especially at the base, the branches spikelet-bearing from the base; spikelets usually falling entire; glumes equal, narrowed to an obtuse tip,

scabrous on back and keel, 2 mm long; lemma 1 mm long, awnless, truncate and toothed at apex; palea nearly as long as lemma. Moist ground at seaports from ballast, City of Newport News. Introduced.

Agrostis tenuis Sibth. (= *A. capillaris* L.). Colonial bent. Browntop. Rhode Island bentgrass.

Culms slender, erect, tufted, usually 20-40 cm tall, with short stolons but no creeping rhizomes; ligule short, less than 1 mm or on the culm as much as 2 mm long; blades mostly 5-10 cm long, 1-3 mm wide; panicle mostly 5-10 cm long, open, delicate, the slender branches naked below, the spikelets not crowded. Cultivated for pastures and lawns; escaped and well established in Coastal Plain, Fall Belt, Blue Ridge and western mountains. May not be native.

Agrostis palustris Huds. Creeping bent.

Differing from *A. stolonifera* chiefly in the long stolons, the narrow stiff appressed blades, and the condensed (sometimes somewhat open) panicle. Marshes along the coast in Accomack, York, Surry Counties and City of Suffolk.

Agrostis stolonifera L. Creeping bent. Red top.

Culms ascending from a spreading base, the decumbent portion rooting in wet soil, 20-50 cm tall; ligule as much as 6 mm long; blades flat, mostly 1-3 mm wide; panicle oblong, 5-15 cm long, pale or purplish, somewhat open, the branches or some of them spikelet-bearing from near the base; spikelets 2-2.5 mm long; glumes acute, glabrous except the scabrous keel; lemma shorter than the glumes, awnless or rarely awned from the back; palea usually half to two-thirds as long as the lemma. Moist grassy places throughout the state.

Agrostis alba L. Redtop. Bentgrass.

Differing from *A. stolonifera* in its usually erect more robust culms, sometimes as much as 1-1.5 m tall, the base erect or decumbent, with strong creeping rhizomes; blades flat, 5-10 mm wide; panicle pyramidal-oblong, reddish, as much as 20 cm long, the branches spreading in anthesis, sometimes contracting later; lemmas rarely awned. The common redtop cultivated for meadows, pastures and lawns, extensively escaped throughout the state. Apparently not native in America.

Agrostis elliottiana Schult. No common name known.

Annual; culms slender, erect or decumbent at base, 10-40 cm tall; blades flat, about 1 mm wide; panicle finally diffuse, about half the entire height of the plant, the branches capillary, fascicled, the spikelets toward the ends of the branchlets, the whole panicle breaking away at maturity; spikelets 1.5-2 mm long; glumes acute; lemma 1-1.5 mm long, minutely toothed, awned below the tip, the awn very slender, flexuous, delicately short-pilose, 5-10 mm long, sometimes falling at maturity; palea wanting. Fields, waste places and open ground of Fall Belt and Piedmont.

Agrostis hiemalis (Walt.) B.S.P. Spring hairgrass, Hairgrass. Fly-away grass. Winter bentgrass. Ticklegrass.

Culms mostly 30-40 cm tall, erect in small tufts, glabrous; blades crowded toward the base in a dense cluster, 3-5 cm long, less than 1 mm wide, flat or subfiliform; panicles fragile, the slender filiform branches in rather distant whorls, widely spreading or drooping, unbranched below the middle, spikelet-bearing only at the ends of the branchlets; spikelets 1.5-1.7 mm long, clustered, short-pedicel, appressed; glumes subequal, acute, scabrous on the keels; lemma 1-1.2 mm long,

the callus glabrous; anthers 0.2 mm long. Open ground, fields and waste places throughout the state.

Agrostis scabra Willd. Rough bentgrass. Hairgrass.

Culms 30-85 cm, rarely to 100 cm tall, erect in small dense tufts; sheaths shorter than the internodes, glabrous; ligule hyaline, 2-5 mm long; blades flat, 8-20 cm long, 1-3 mm wide, scabrous, the basal ones often subfiliform; panicles 15-25 cm long, rarely longer, the brittle scabrous branches in rather distant verticils, ascending or spreading, sometimes drooping, branching above the middle; spikelets 2-2.7 mm long, loosely arranged at the ends of the branchlets; glumes unequal, acuminate, scabrous on the keels; lemma 1.5-1.7 mm long, distinctly longer than the caryopsis, the callus sparsely pilose; anthers 0.4-0.5 mm long. Mountain meadows, fields and open woods. Probably introduced.

Agrostis borealis Hartm. Bentgrass.

Culms tufted, 20-40 cm tall, or, in alpine plants, dwarf; leaves mostly basal, the blades 5-10 cm long, 1-3 mm wide; panicle pyramidal, 5-15 cm long, the lower branches whorled and spreading; glumes 2.5-3 mm long, acute; lemma a little shorter than the glumes, awned, the awn usually bent and exserted; palea obsolete or nearly so. Rocky slopes and moist banks at high altitudes, White Top Mt., Grayson County.

Agrostis perennans (Walt.) Tuckerm. Autumn bent. Thin grass. Upland bent.

Culms erect to somewhat decumbent at base, varying from weak and lax to relatively stout, 30-100 cm tall, often with lax leafy shoots at base; leaves rather numerous, the blades from lax to stiffly upright, corresponding to the culms, 10-20 cm long, 1-6 mm wide; panicle pale to tawny, open, oblong, the branches verticillate, mostly lax, ascending, branching about the middle, spikelets 2-3.2, mostly 2.2-2.7 mm long, the pedicels spreading, but the spikelets sometimes somewhat aggregate toward the ends of the branchlets; glumes acute or acuminate; the first slightly longer; lemma 1.5-2 mm long, rarely awned; palea obsolete or nearly so. Open ground, old fields, open woods in rather dry soil throughout the state.

Agrostis altissima (Walt.) Tuckerm. No common name known.

Culms mostly stouter than in *A. perennans*, erect or ascending, panicle branches usually ascending, the spikelets more or less aggregate toward the ends; spikelets 2.3-3.7, mostly 2.7-3.5 mm long. Mostly in marshy ground, pine barren bogs, and wooded swamps of Coastal Plain.

Aira L. Hairgrass

Delicate annual with lax, subfiliform blades and open or contracted panicles; spikelets small, two-flowered; glumes boat-shaped, about equal; lemmas firm, rounded on back, tapering into two slender teeth, a slender geniculate, twisted awn usually exserted on back of lemma.

- 1. Panicle spike-like, dense *A. praecox*
- 1'. Panicle open 2
- 2. Lower floret with awn as long as that of the upper flower *A. caryophyllea*
- 2'. Lower floret awnless or nearly so *A. elegans*

Aira praecox L. No common name known.

Culms tufted, 10-20 cm tall, usually erect; panicle narrow, dense, 1-3 cm long; spikelets yellowish, shining, 3.5-4 mm long; lemmas with awns 2-4 mm long, that of

the lower floret the shorter. Sandy open ground along the coast, Tidewater and Eastern Shore.

Aira caryophyllea L. Silver hairgrass.

Culms solitary or in small tufts, erect, 10-30 cm tall; panicle open, the silvery shining spikelets 3 mm long, clustered toward the ends of the spreading capillary branches; both lemmas with awns about 4 mm long. Open dry ground, Coastal Plain and Piedmont.

Aira elegans Willd. ex Gaudin. (= *A. capillaris* Host.). No common name known.

Resembling *A. caryophyllea*; panicle more diffuse; spikelets 2.5 mm long, scattered at ends of branches; lemma of lower floret awnless or with a minute awn just below the apex, that of the upper floret with an awn 3 mm long. Open ground of Coastal Plain and Piedmont.

Alopecurus L. Foxtail

Annuals or perennials; branching culms, panicles densely flowered, spike-like panicles; spikelets one-flowered, glumes equal, awnless; palea wanting.

1. Spikelets 5-6 mm long 2
- 1'. Spikelets 2-4 mm long 3
2. Panicle slender, tapering at each end; glumes scabrous
on keel; annual *A. myosuroides*
- 2'. Panicle cylindric, dense; glumes conspicuously ciliate on
keel; perennial *A. pratensis*
3. Plants perennial, culms decumbent *A. geniculatus*
- 3'. Plants annual, culms tufted *A. carolinianus*

Alopecurus myosuroides Huds. Foxtail.

Annual; culms tufted, slightly scabrous, 10-50 cm tall, erect or decumbent at base; blades usually 2-3 mm wide; panicle slender, somewhat tapering at each end, 4-10 cm long, 3-5 mm wide; glumes 6 mm long, pointed, whitish with 3 green nerves, glabrous, scabrous on keel, short-ciliate at base; lemma about as long as the glumes, the awn bent, exserted 5-8 mm. Fields, waste places and ballast ground of Arlington, Henrico, James City and Powhatan Counties. Introduced, rare, Eurasia.

Alopecurus pratensis L. Meadow foxtail.

Perennial; culms erect, 30-80 cm tall; blades 2-6 mm wide; panicle 3-7 cm long, 7-10 mm thick; glumes 5 mm long, villose on keel and pubescent on sides; awn exserted 2-5 mm. Fields and waste places, Arlington County. Introduced from Eurasia.

Alopecurus geniculatus L. Water foxtail.

Perennial; culms decumbent, rooting at the nodes, 15-60 cm tall; blades 1-4 mm wide; panicle slender, 2-7 cm long, about 4 mm thick; spikelets 2 mm long, awn of lemma exserted 2-3 mm, giving the panicle a softly bristly appearance; spikelets about 2.5 mm long, the tip dark purple; anthers about 1.5 mm long. In water and wet places, cities of Virginia Beach, and Chesapeake; Arlington, Fairfax and Montgomery Counties.

Alopecurus carolinianus Walt. Field foxtail.

Annual; culms tufted, much branched at base, 10-50 cm tall; similar to *A. geniculatus* but panicle more slender; spikelets 2-2.5 mm long, pale, awn exserted

2-3 mm; anthers about 0.5 mm long. Moist open ground, old fields and wet places of Coastal Plain.

Ammophila Host. Beachgrass

Tough, rather coarse, erect perennials with hard, scaly, creeping rhizomes; blades long, tough, involute; panicles pale, dense, spikelike; spikelets 1-flowered, compressed, rachis disarticulating above glumes, produced beyond palea as a short bristle, hairy above; glumes about equal, chartaceous; lemma similar to but a little shorter than glumes, callus bearded; palea nearly as long as lemma.

Ammophila breviligulata Fern. American beachgrass. Beachgrass. Psamma. Marram.

Culms in tufts, commonly 70-100 cm tall with deep strong extensively creeping rhizomes, the base of the culms clothed with numerous broad overlapping sheaths; ligule firm, 1-3 mm long; blades elongate, firm, soon involute, curved forward past the culm, the scaberulous upper surface curved downward; panicle pale, 15-30 cm long, nearly cylindrical spikelets 11-14 mm long; glumes scaberulous, the first 1-nerved, the second 3-nerved; lemma scabrous, the callus hairs about 2 mm long, the rachilla about 3 mm long. Sand dunes along the coast.

Amphicarpum Kunth

Annual or perennial erect grasses with flat blades and narrow terminal panicles. Spikelets of 2 kinds on the same plant, one perfect but not fruitful in a terminal panicle, the other cleistogamous on slender leafless subterranean branches from base of culm or sometimes from lower nodes; first glume of aerial spikelets variable in size, sometimes obsolete; second glume and sterile lemma about equal; lemma and palea indurate; fruiting spikelets much larger, first glume wanting; second glume and sterile lemma strongly nerved, subrigid, exceeded at maturity by the turgid, elliptic, acuminate fruit with strongly indurate lemma and palea.

Amphicarpum purshii Kunth. No common name known.

Annual; culms erect, 30-80 cm tall, the leaves crowded toward the base, hirsute; blades erect, 10-15 cm long, 5-15 mm wide, sharp-pointed; panicle 3-20 cm long; spikelets elliptic, 4-5 mm long; subterranean spikelets 7-8 mm long, plump, acuminate. Sandy pinelands of Eastern Shore.

Andropogon L. Beardgrass

Perennial; culms solid; spikelets in racemes, aggregate on a common peduncle which is usually enclosed by a spathe-like sheath, in pairs at each joint of rachis, one sessile and perfect, the other stalked and staminate or rudimentary; glumes nearly equal; sterile lemma shorter than glumes; fertile lemma usually bearing a bent and twisted awn from the apex or between the lobes; palea small or wanting.

- 1. Racemes solitary on each peduncle 2
- 1'. Racemes two to numerous on each peduncle 3
- 2. Culms erect; sessile spikelet 6-8 mm long; hairs on rachis and sterile pedicel inconspicuous *A. scoparius*
- 2'. Culms decumbent at base; sessile spikelets about 1 cm long; hairs on rachis and sterile pedicel rather prominent *A. littoralis*
- 3. Pedicillate spikelet staminate, similar to sessile spikelet but awnless *A. gerardii*
- 3'. Pedicillate spikelet reduced to 1 or 2 glumes, or obsolete, the pedicel only developed 4

4. Inflorescence very decompound, only profuse pairs of racemes aggregate in an elongate or corymbose mass . . . *A. glomeratus*
- 4'. Inflorescence not conspicuously decompound nor dense . . . 5
5. Peduncle not more than 1 cm long, the dilated spathes exceeding the 2 (occasionally 3 or 4) racemes 6
- 5'. Peduncles 2 cm long or more 7
6. Upper sheaths inflated, spathe-like, aggregate, the late inflorescence a flabellate tuft *A. elliottii*
- 6'. Upper sheaths not inflated and aggregate *A. virginicus*
7. Peduncles not more than 5 cm long, enclosed in the spathe or only slightly exserted *A. mohrii*
- 7'. Peduncles or most of them 5 to 15 cm long, mostly long-exserted 8
8. Upper sheaths inflated, overlapping, conspicuous *A. elliottii*
- 8'. Upper sheaths not inflated, overlapping nor conspicuous . . . *A. ternarius*

Andropogon scoparius Michx. Little bluestem. Small bluestem. Broom beardgrass. Prairie beardgrass. Broom. Wiregrass.

Plants green or glaucous, often purplish, culms tufted, from slender to robust, compressed, 50-150 cm tall, erect, the upper half freely branching; sheaths and blades commonly glabrous or nearly so, frequently sparsely pilose at their junction, rarely pubescent to villose throughout, the blades 3-6 mm wide, flat; raceme 3-6 cm long, mostly wholly or partly included in the sheaths, commonly spreading, the rachis slender, flexuous, pilose, sometimes copiously so; sessile spikelet mostly 6-8 mm long, scabrous, the awn 8-15 mm long; pedicellate spikelet usually reduced, short-awned, spreading, the pedicel pilose. Open woods, dry hills and fields throughout the state.

Andropogon littoralis Nash. Dune bluestem.

Resembling *A. scoparius*, but culms more compressed, with broad, keeled, overlapping lower sheaths, often bluish-glaucous, the flat tufts crowded on a slender rhizome, decumbent or bent at base; blades 4-6 mm wide; rachis joints and pedicels copiously long-villose. Sandy shores, moist to wet soil along shores of Coastal Plain.

Andropogon gerardii Vitman. Big bluestem. Turkey foot. Turkey claw. Beardgrass.

Plants often glaucous; culms robust, often in large tufts, sometimes with short rhizomes, 1-2 m tall, usually sparingly branching toward the summit; lower sheaths and blades sometimes villose, occasionally densely so, the blades flat, elongate, mostly 5-10 mm wide, the margins very scabrous; racemes on the long-exserted terminal peduncle mostly 3 to 6, fewer on the branches, 5-10 cm long, usually purplish, sometimes yellowish; rachis straight, the joints and pedicels stiffly ciliate on one or both margins, the joints hispid at base; sessile spikelet 7-10 mm long, the first glume slightly sulcate, usually scabrous, the awn geniculate and tightly twisted below, 1-2 cm long; pedicellate spikelet not reduced, but slightly so, awnless, staminate. Dry soil, weedy fields and roadsides throughout the state.

Andropogon glomeratus (Walt.) B.S.P. Bushy beardgrass.

Culms erect, 50-150 cm tall, compressed, with broad keeled overlapping lower sheaths, the flat tufts often forming dense, usually glaucous, clumps, the culms

branching toward the summit; sheaths occasionally villose; blades elongate, 3-8 mm wide; inflorescence dense, feathery, from flabellate to oblong, the paired racemes 1-3 cm long, about equalling the slightly dilated spathes, the enclosed peduncle and ultimate branchlets long-villose, peduncle at least 5 mm long, often longer; rachis very slender, flexuous, long-villose; sessile spikelets 3-4 mm long, the awn straight, 1-1.5 cm long; sterile spikelet reduced to a subulate glume or wanting, the pedicel slender, long-villose. Low moist ground, marshes and swamps, scattered throughout the state; however, mostly in Piedmont and Coastal Plain.

Andropogon elliotii Chapm. Elliott beardgrass.

Culms tufted, erect, 30-80 cm tall, at first nearly simple, later branching toward the summit; lower sheaths keeled, rather narrow, commonly loosely pilose, those near the summit inflated and spathe-like, crowded, the very short internodes densely bearded, blades flat, 3-4 mm wide; primary inflorescence of few to several racemes, mostly in pairs, rarely threes or fours, one filiform, often strongly flexuous peduncles, long-exserted from inconspicuous spathes, these on slender branchlets, borne in the axils of broad, spathe-like sheaths of the main culm; secondary inflorescences on short peduncles from broad spathes; racemes flexuous, 3-4 cm long, rachis joints and pedicels long-villose; sessile spikelet 4-5 mm long, the awn somewhat twisted, 10-15 mm long; pedicellate spikelets obsolete or nearly so. Open ground, old fields and open woods scattered throughout the state.

Andropogon virginicus L. Broomsedge. Virginia broomsedge. Broomsedge bluestem.

Culms erect, 50-100 cm tall, usually in rather small tufts, the upper two-thirds mostly freely branching; lower sheaths compressed, keeled, equitant; sheaths glabrous or more or less pilose along the margins, occasionally conspicuously so; ligule strongly ciliate; blades folded or flat, 2-5 mm wide, pilose on upper surface toward base; inflorescence elongate, narrow, the 2 to 4 racemes 2-3 cm long, partly included and shorter than the inflated tawny to bronze spathes; rachis very slender, flexuous, long-villose; sessile spikelet about 3 mm long, the delicate straight awn 1-2 cm long; pedicel long-villose, its spikelet obsolete or nearly so. Open ground, old fields, open woods, sterile hills and sandy soil throughout the state.

Andropogon mohrii (Hack.) Hack. ex Vasey. No common name known.

Culms stout, compressed, tufted, erect, 80-130 cm tall, the upper half sparingly to rather freely branching; leaves villose, the lower sheaths strongly keeled and glabrous at base, the blades elongate, 3-5 mm wide; inflorescence narrow, the branches approximate, the ultimate branchlets short, densely bearded at summit, the purplish spathes 4-6 cm long; racemes mostly 4, tawny, 2-4 cm long, on peduncles mostly about 2 cm long, or the terminal ones sometimes long-exserted; rachis scarcely flexuous, the joints shorter than the spikelets, copiously long-villose; sessile spikelet 4-5 mm long, the awn loosely twisted below, 1.5-2 cm long; pedicel long-villose, the spikelet reduced to a minute glume. Wet pine woods of Prince George County.

Andropogon ternarius Michx. Silverbeard. Split beard bluestem.

Culms tufted, erect, 80-120 cm tall, the upper half to two-thirds branching, the branches usually long, slender and erect; leaves often purplish-glaucous, glabrous, or the lower loosely villose, the blades 2-4 mm wide; inflorescence elongate, loose, of few to many pairs of silvery to creamy or grayish feathery racemes, usually on

long-exserted peduncles from slender inconspicuous spathes, some of the lateral peduncles often short, from dilated spathes, rarely most of them so; racemes 3-6 cm long, with mostly less than 12 joints, the rachis not flexuous, the joints shorter than the spikelets, copiously long-villose; sessile spikelets 5-7 mm long, glabrous and nerveless between the keels, the awn twisted below, 1.5-2 cm long; pedicel long-villose, the spikelet obsolete or nearly so. Dry sandy soil and open woods mostly in south central to eastern part of the state.

Anthoxanthum L. Vernalgrass

Sweet smelling annuals or perennials; panicles terminal; spikelets with one terminal perfect floret and two sterile lemmas; glumes unequal, acute or mucronate; sterile lemmas shorter than glumes, awned from back; fertile lemma awnless, shorter than sterile ones; palea rounded on back, enclosed in lemma.

1. Plants perennial *A. odoratum*
- 1'. Plants annual *A. aristatum*

Anthoxanthum odoratum L. Sweet vernalgrass.

Perennial; culms tufted, erect, slender, 30-60 cm tall, rarely to 1 m tall; blades 2-5 mm wide; panicle long-exserted, brownish-yellow, acute, 2-6 cm long; spikelets 8-10 mm long; glumes scabrous, the first about half as long as the second; sterile lemmas subequal, appressed-pilose with golden hairs, the first short-awned below the apex, the second awned from near the base, the awn twisted below, geniculate, slightly exceeding the second glume; fertile lemma about 2 mm long, brown, smooth and shining. Meadows, pastures and waste places throughout the state. Introduced from Eurasia.

Anthoxanthum aristatum Boiss. (= *A. puelli* Lecoq & Lamotte). No common name known.

Differing from *A. odoratum* in being annual, the culms lower, often geniculate and bushy branching; panicles looser; spikelets a little smaller. Waste places scattered throughout the state; Introduced from Europe.

Aristida L. Three-awn

Annual or perennial; slender tufted grasses; panicles narrow or some times open; spikelets 1-flowered; glumes equal or unequal, narrow, acute, acuminate or awn-tipped; lemma indurate, narrow, terete, convolute, with a hard, sharp-pointed callus terminating above in a usually trifid awn.

1. Lemma articulate with the column of the awns *A. tuberculosa*
- 1'. Lemma not articulate 2
2. Central awn spirally coiled at base, the lateral straight . . . 3
- 2'. Central awn not spirally coiled 4
3. Glumes nearly equal, 6 to 8 mm long; lemma 5 to 6 mm long *A. dichotoma*
- 3'. Glumes unequal, the second longer, about 1 cm long; lemma about 1 cm long *A. curtissii*
4. Plants annual 5
- 4'. Plants perennial 6
5. Awns mostly 4 to 7 cm long, about equal, divergent *A. oligantha*
- 5'. Awns mostly less than 2 cm long, often unequal *A. longespica*
6. Sheaths lanate-pubescent *A. lanosa*
- 6'. Sheaths not lanate-pubescent 7

7. Awns at maturity about equally divergent, sometimes slightly twisted but not spirally contorted at base *A. purpurascens*
 7. Awns at maturity unequally divergent or spirally contorted at base *A. virgata*
Aristida tuberculosa Nutt. No common name known.

Annual; culms branching, 30-60 cm or even 1 m tall; blades involute, 2-4 mm wide when flat; panicle 10-20 cm tall, the branches stiffly ascending; glumes about equal, gradually narrowed into an awn, about 2.5 cm long, including the awn; lemma 11-13 mm long, glabrous except for the slightly scabrous summit, extending downward into a densely pubescent callus 3-4 mm long; column of awns twisted, 10-15 mm long, the upper 2 or 3 mm twisted but not united, above this forming a semicircular bend, the terminal straight part of the awns usually deflexed, 3-4 cm long. Open sandy woods of Eastern Shore.

Aristida dichotoma Michx. Triple-awn grass. Three-awn. Poverty grass.

Annual; culms branched at base, 20-40 cm tall; blades short, the lower mostly flat, scarcely 1 mm wide, the upper involute; panicles terminal and axillary, the terminal usually less than 10 cm long, the lateral small; glumes about equal, 6-8 mm long; lemma 5-6 mm long; central awn spirally coiled, horizontally bent, 3-6 mm long, the lateral awns erect, about 1 mm long. Dry open ground throughout the state.

Aristida curtissii (A. Gray) Nash. No common name known.

Annual; similar to *A. dichotoma*, differing in the less branching habit, the longer and more conspicuous blades, the looser panicles of larger spikelets, the more unequal glumes, the longer second glume (about 1 cm long), the longer smooth lemma (about 1 cm long) and central awn, and the usually longer lateral awns; the central awn about 1 cm long, the lateral awns 2-4 mm long. Open dry ground scattered throughout the state.

Aristida oligantha Michx. Prairie three-awn. Whitegrass. Wiregrass. Needlegrass. Triple-awned grass.

Annual; much branched; culms 30-50 cm tall; blades flat or loosely involute, usually not more than 1 mm wide; panicle loose, 10-20 cm long; spikelets short-pedicelled, the lower often in pairs; glumes about equal, 2-3 cm long, tapering into an awn, the first 3-to 5-nerved; lemma about 2 cm long, the awns about equal, divergent, 4-7 cm long, somewhat spirally curved at base. Open dry ground throughout the state except for the southwest portion.

Aristida longespica Poir. No common name known.

Annual, branched; culms 20-40 cm tall; blades flat or involute, about 1 mm wide; panicles narrow, slender, the terminal 10-15 cm or even 20 cm long; glumes about equal, 5 mm long; lemma 4-5 mm long; central awn sharply curved at base, spreading, 5-15 mm long, the lateral awns erect, one-third to half as long as the central, sometimes only 1 mm long. Sterile or sandy soil scattered throughout the state.

Aristida lanosa Muhl. ex Ell. Woolly triple-awn grass.

Perennial; culms solitary or few in a tuft, rather robust, 1-1.5 m tall; sheaths lanate-pubescent or rarely glabrous; blades flat, elongate, as much as 4 mm wide; panicle narrow, rather loose, as much as 40 cm long; first glume 12-14 mm, the second about 10 mm; lemma 8-9 mm long; central awn horizontally spreading or

reflexed from a curved base, 1.5-3 cm long, the lateral half to two-thirds as long, erect or spreading. Dry sandy soil of the Coastal Plain and eastern Piedmont.

Aristida purpurascens Poir. Arrowfeather.

Perennial; culms tufted from a rather thin, weak, sometimes decumbent base, slender, 40-70 cm or even 1 m tall; blades flat, rather lax and flexuous (especially the old ones), usually less than 2 mm wide; panicle narrow, rather lax and nodding, one-third to half the entire length of the plant; glumes about equal, mostly 8-12 mm long; lemma about 7 mm long; awns about equal, divergent or somewhat reflexed, 1.5-2.5 cm long. Dry sandy soil mostly in central and eastern part of the state.

Aristida virgata Trin. No common name known.

Perennial; culms tufted from a rather slender soft base, erect, 50-80 cm tall; blades flat, rather lax, usually not more than 2 mm wide; panicle slender, erect, though not very stiff, rather loosely flowered, one-third to half the entire length of the culm; glumes about equal, 6-7 mm long; lemma 4-5 mm long; central awn horizontally spreading or somewhat reflexed, 1.5-2 cm long, the lateral awns erect, about two-thirds as long as the central. Moist sandy soil of the Coastal Plain. Harvill *et al.* list *A. virgata* as a synonym of *A. purpurascens*.

Arrhenatherum Beauv.

Rather tall perennial with flat blades and narrow panicles; spikelets 2-flowered, the lower floret staminate, the upper perfect, the rachilla disarticulating above the glumes and produced beyond the florets; glumes rather broad and papery, the first 1-nerved, the second 3-nerved; lemmas 5-nerved, hairy on the callus, the lower bearing near the base a twisted geniculate exerted awn, the upper with a short straight slender awn just below the tip.

Arrhenatherum elatius (L.) Presl. Tall oatgrass. Evergreen grass.

Culms erect, 1-1.5 m tall; blades flat, scabrous, 5-10 mm wide; panicle pale or purplish, shining, 15-30 cm long, the short branches verticillate, spreading in anthesis, usually spikelet-bearing from the base; spikelets 7-8 mm long; glumes minutely scabrous; lemmas scabrous, the awn of the staminate floret about twice as long as its lemma. Meadows, open ground, and waste places throughout the state.

Arthraxon Beauv.

Low creeping grass with broad cordate-clasping blades and subflabellate panicles; spikelets perfect, usually awned, sessile, the secondary spikelet and its pedicel wanting or the pedicel developed only at the lower joints of the filiform rachis; racemes terminating branches of a dichotomously forking panicle, in appearance subdigitate or fascicled.

Arthraxon hispidus (Thunb.) Makino. No common name known.

Annual; culms slender, branching, decumbent or creeping, 20-100 cm long; sheaths hispid; blades ovate to ovate lanceolate, 2-5 cm long, 5-15 mm wide, ciliate toward base; panicles of few to several racemes, flabellate, contracting toward maturity, on filiform peduncles; rachis joints glabrous; spikelets 4-5 mm long, the strong nerves aculeate-scabrous; sterile lemma with a slender geniculate awn. Pastures, lawns, and open ground throughout the state.

Arundinaria Michx. Cane.

Perennial woody plants; spikelets 8- to 12-flowered, large, compressed; glumes unequal, shorter than the lemmas; lemmas papery, rather fragile, acute, acuminate,

mucronate or awn-tipped; palea about as long as the lemma, prominently 2-keeled and deeply sulcate between keels.

1. Primary branches erect or nearly so; individual culms with oblong-linear branches; spikelets usually rather loose . . . *A. gigantea*

1'. Primary branches ascending at 45° angle; individual culms with broadly lancolate branches; spikelets rather compact . *A. tecta*
Arundinaria gigantea (Walt.) Muhl. Giant cane. Large cane.

Culms 2-10 m high, branching; leaves 1.5-3 cm wide, tapering at each end; panicles on leafy branches bearing loose sheaths and small blades; spikelets 8- to 12-flowered, 3-7 cm long, on slender-angled pedicels 2-30 mm long, hirsute to nearly glabrous; glumes distant, acuminate, pubescent, the lower minute, sometimes wanting; lemmas broadly lanceolate, keeled, mostly 1.5-2 cm long, sometimes tapering into an awn 4 mm long, ciliate, appressed-hirsute to canescent; rachilla segments densely hirsute; palea scabrous on the keels. Forming extensive colonies in low woods, river banks, moist ground scattered throughout the state.

Arundinaria tecta (Walt.) Muhl. Switch cane. Small cane.

Similar to *A. gigantea*, the culms usually not more than 2 m tall, the sheaths more commonly as long as the internodes; blades on the average a little longer and narrower; inflorescence similar, spikelets 6- to 12-flowered, 3-5 cm long, relatively compact; glumes obtuse to acuminate, often glabrous or nearly so; lemmas scarcely keeled, glabrous or minutely canescent at the base; rachilla strigose. Forming colonies in swampy woods, moist pine barrens and live oak woods; sandy margins of streams of coastal plain and scattered in western part of state.

Arundo L.

Tall perennial reeds with broad linear blades and large plumelike terminal panicles, spikelets several-flowered, the florets successively smaller, the rachilla glabrous, disarticulating above glumes and between florets; glumes somewhat unequal, membranaceous, 3-nerved, narrow, tapering into a slender point; lemmas thin, 3-nerved, densely and softly long-pilose, two outer nerves ending in slender teeth, middle nerve extending into a straight awn.

Arundo donax L. Giant Reed.

Culms stout, in large clumps, 2-6 m tall, sparingly branching, from thick knotty rhizomes; blades numerous, elongate, 5-7 cm wide on the main culm, conspicuously distichous, spaced rather evenly along the culm, the margin scabrous; panicle dense, erect, 30-60 cm long; spikelets 12 mm long. Frequently cultivated for ornament in eastern part of state; also in Pulaski County along New River. Introduced from warm regions of Old World.

Avena L. Oats

Low or moderately tall annuals; panicles narrow or open, usually few-flowered with large, 2- to 3-flowered spikelets; glumes about equal, membranaceous or papery, longer than lower floret; lemmas indurate, except toward summit, bearing dorsal, bent and twisted awn.

1. Spikelets mostly 2-flowered; awn usually straight or wanting; lemmas glabrous *A. sativa*

1'. Spikelets mostly 3-flowered; awn stout, geniculate, twisted; lemmas with stiff brown hairs *A. fatua*

Avena sativa L. Oats.

Annual, culms rather stout, erect, up to 75 cm tall; leaves numerous and well developed; panicle loose, open, erect, the branches slender, spreading, or sometimes drooping; spikelets usually 2-flowered, about 2 cm long exclusive of awns, the florets not readily separating from the glumes; glumes about equal, many nerved, papery, overtopping the uppermost floret; lemmas glabrous; awn usually straight, often wanting. Commonly cultivated and occasionally escaped.

Avena fatua L. Wild Oats.

Culms 30-75 cm tall, erect, stout; leaves numerous, the blades flat, usually scabrous; panicle loose and open, the slender branches usually horizontally spreading; spikelets usually 3-flowered; glumes about 2.5 cm long; rachilla and lower part of the lemma clothed with long stiff brownish, or sometimes whitish, hairs, these sometimes scant; florets readily falling from the glumes; lemmas nerved above, about 2 cm long, the teeth acuminate, not setaceous; awn stout, geniculate, twisted below, 3-4 cm long. Cultivated soil and waste places of Montgomery County. Introduced from Europe.

Axonopus Beauv. Carpetgrass.

Stoloniferous or tufted perennial; culms compressed, tufted, erect, decumbent or stoloniferous; racemes slender, spike-like, digitate or racemose along main axis; spikelets depressed-biconvex, oblong, solitary, subsessile, alternate, in 2 rows on one side of a 3-angled rachis; first glume wanting; second glume and sterile lemma equal, lemma without palea; fertile lemma indurate, oblong-elliptic, and back turned from rachis; palea indurate.

1. Spikelets 4-5 mm long, glabrous; midnerve of glume and sterile lemma evident *A. furcatus*

1'. Spikelets 2-3 mm long, sparsely appressed-silky; midnerve of glume and sterile lemma suppressed *A. affinis*

Axonopus furcatus (Flugge) Hitchc. No common name known.

Plants stoloniferous; culms compressed, tufted, erect, or decumbent at base, 40-100 cm tall; blades flat, mostly 5-10 mm wide, glabrous, ciliate, or even hirsute; racemes 2, digitate, rarely a third below, spreading, 50-100 cm long; spikelets 4-5 mm long (rarely less), glabrous, acute; glume and sterile lemma 5-nerved; fruit two-thirds as long as the spikelet. Marshes, river banks and moist pine barrens of Coastal Plain.

Axonopus affinis Chase. Carpetgrass. Common carpetgrass.

Tufted or stoloniferous; culms slender, glabrous, 25-35 cm tall, rarely as much as 75 cm, sometimes forming dense mats; sheaths compressed, keeled; blades as much as 28 cm long, usually less than 15 cm, 2-6 mm wide, flat or folded; racemes 2 to 4, 2-10 cm long, ascending; spikelets 2 mm long, oblong-elliptic, subacute, the second glume and sterile lemma covering the fruit or slightly pointed beyond it, sparsely silky-pilose. Moist, mucky or sandy meadows, open woods and waste places of Fairfax County and Virginia Beach.

Bouteloua Lag. Grama.

Perennial or sometimes annual, low or rather tall grasses with 2 to several or many spikes racemose on a common axis; spikelets 1-flowered, with the rudiments of 1 or more florets above, sessile, in 2 rows along one side of rachis; glumes 1-nerved, acuminate or awntipped, the first shorter and narrower; lemma as long as second glume or a little longer, 3-nerved, the nerves extending into short awns or mucros; palea sometimes 2-awned; a second rudimentary floret sometimes present.

Bouteloua curtipendula (Michx.) Torr. Side-oats grama. Grama grass. Tall grama grass. Mesquite grass.

Perennial, with scaly rhizomes; culms erect, tufted, 50-80 cm tall; blades flat or subinvolute, 3-4 mm wide, scabrous; spikes 35 to 50, 1-2 cm long, purplish, spreading or pendulous and mostly twisted to one side of the slender axis, this 15-25 cm long; spikelets 5 to 8, appressed or ascending, 6-10 mm long; fertile lemma acute, mucronate; rudiment with 3 awns and subacute intermediate lobes, often reduced and inconspicuous. Dry fields, shale barrens of Valleys and Ridges. Core et al. call it a handsome species.

Brachiaria (Trin.) Griseb.

Branching and spreading annuals or perennials, with linear blades and several spreading or appressed racemes approximate along a common axis; spikelets solitary, rarely in pairs, subsessile, in 2 rows on one side of a 3-angled, sometimes narrowly winged rachis; first glume turned toward rachis, short to nearly as long as spikelet; second glume and sterile lemma about equal, 5- to 7-nerved, lemma enclosing a hyaline palea and sometimes a staminate flower; fertile lemma indurate, usually papillose-rugose, the margins inrolled, apex rarely mucronate or with a short awn.

Brachiaria platyphylla (Griseb.) Nash. Broadleaf signalgrass.

Annual; culms decumbent, rooting at the lower nodes; blades rather thick, 4-12 cm long, 6-12 mm wide; panicle short-exserted or included at the base; racemes 2 to 6, distant, 3-8 cm long, ascending or spreading, the rachis winged, 2 mm wide; spikelets oval, 4-4.5 mm long, about 2 mm wide; first glume scarcely one-third the length of the spikelet, blunt; second glume and sterile lemma equal, exceeding the first and forming a flat beak beyond it, 3- to 5-nerved, with transverse veinlets toward the summit; fruit 3 mm long, elliptic, papillose-roughened. Low sandy open ground of Coastal Plain.

Brachyelytrum Beauv.

Erect, slender perennials with short, slender knotty rhizomes, flat blades and narrow, rather few-flowered panicles; spikelets 1-flowered, rachilla disarticulating above glumes, prolonged behind palea as a slender naked bristle; glumes minute, the first often obsolete, the second sometimes awned; lemma firm, narrow, 5-nerved, base extending into a pronounced oblique callus, the apex terminating in a long straight scabrous awn.

Brachyelytrum erectum (Schreb.) Beauv. Long-awned wood grass.

Culms 60-100 cm tall; sheaths sparsely retrorse-hispid, rarely glabrous; blades mostly 7-15 cm long, 1-1.5 cm wide, scabrous, sparingly pilose beneath, at least on the nerves and margin; panicle 5-15 cm long, the short branches appressed; second

glume 0.5-2 mm long; lemma subterete, about 1 cm long, scabrous, the nerves sometimes hispid, the awn 1-3 cm long. Moist or rocky woods throughout the state.

Briza L. Quaking grass.

Low annuals or perennials with erect culms, flat blades and usually open, showy panicles with capillary pedicels; spikelets several-flowered, broad, often cordate, florets crowded and spreading horizontally, rachilla disarticulating above glumes and between florets; glumes about equal, broad, papery-chartaceous with scarious margins; lemmas papery, broad with scarious spreading margins, cordate at base, several-nerved, nerves often obscure, apex obtuse or acutish; palea much shorter than lemma.

Briza minor L. Little quaking grass. Small quaking grass.

Annual; culms erect, 10-40 cm tall; ligule of the upper leaf 5 mm long or more, acute; blades 2-10 mm wide; panicle 5-12 cm long, the branches stiffly ascending; the spikelets pendent, triangular-ovate, 3- to 6-flowered, about 3 mm long. Infrequent in the state. Introduced from Europe.

Bromus L. Brome grass

Native perennials and introduced annuals; culms low or rather tall with closed sheaths, usually flat blades; open or contracted panicles of large spikelets; spikelets several- to many-flowered, rachilla disarticulating above glumes and between florets; glumes unequal, acute; lemmas convex on back or keeled, 2-toothed, awned from between the teeth or awnless; palea usually shorter than lemma, ciliate on keel.

1. Spikelets strongly flattened, lemma compressed-keeled . . . *B. catharticus*
- 1'. Spikelets terete before anthesis or somewhat flattened; lemmas not compressed-keeled 2
2. Plants perennial 3
- 2'. Plants annual 8
3. Creeping rhizomes present *B. inermis*
- 3'. Creeping rhizomes wanting 4
4. Lemmas pubescent along margin and lower part of back, upper part glabrous *B. ciliatus*
- 4'. Lemmas pubescent rather evenly over the back, usually more densely so along the lower part of the margin 5
5. Panicle branches lax or drooping; blades along culm mostly elongate *B. kalmii*
- 5'. Panicle larger, usually erect, branches more or less drooping; blades mostly wide and lax 6
6. Sheaths shorter than internodes, nodes 4 to 6 *B. purgans*
- 6'. Sheaths as long or longer than internodes, nodes 6 to 20 7
7. Second glume 5-nerved; nodes 6 to 8; sheaths flangeless at mouth *B. nottawayanus*
- 7'. Second glume 3-nerved; nodes 10 to 20; sheaths with prominent flanges at mouth *B. latiglumis*
8. Lemmas broad, rounded above, not acuminate, teeth mostly less than 1 mm long 9
- 8'. Lemmas narrow, with a sharp callus, gradually acuminate, bifid, teeth 2-5 mm long 15

9. Panicle contracted, rather dense; branches erect
or ascending 10
 - 9'. Panicle open; branches spreading 12
 10. Lemmas glabrous *B. racemosus*
 - 10'. Lemmas pubescent 11
 11. Spikelets compressed; lemmas thin and narrow with
finally divaricate awn *B. scoparius*
 - 11'. Spikelets turgid; lemmas rather thick, broad *B. mollis*
 12. Foliage glabrous *B. secalinus*
 - 12'. Foliage pubescent 13
 13. Branches of panicle rather stiffly spreading or drooping,
not flexuous, awn straight *B. commutatus*
 - 13'. Branches lax or flexuous, usually slender 14
 14. Palea distinctly shorter than its lemma; awn flexuous,
usually somewhat divergent in drying; spikelets
rather turgid *B. japonicus*
 - 14'. Palea about as long as its lemma; awn straight or
nearly so in drying; spikelets thinner and flatter,
scarcely turgid *B. arvensis*
 15. Panicle contracted, erect; awn 16-22 mm long *B. madritensis*
 - 15'. Panicle open, the branches spreading; awn 2-14 mm long 16
 16. Second glume usually less than 1 cm long; pedicels capillary,
flexuous *B. tectorum*
 - 16'. Second glume more than 1 cm long; pedicels somewhat
flexuous but not capillary 17
 17. Awn about 2 cm long; first glume 8 mm long *B. sterilis*
 - 17'. Awn 3-5 cm long; first glume about 15 mm long *B. rigidis*
- Bromus catharticus* Vahl. (= *B. unioloides* H.B.L.; = *B. willdenowii* Kunth. See Gould and Shaw, 1983). Rescue grass. Shrader's brome grass. Smooth brome grass. Awnless brome grass. Hungarian brome.

Annual or biennial; culms erect to spreading, as much as 100 cm tall; sheaths glabrous or pubescent; blades narrow, glabrous or sparsely pilose; panicle open, as much as 20 cm long, the branches as much as 15 cm long, naked at base, in small plants the panicles reduced to a raceme of a few appressed short-pedicled spikelets; spikelets 2-3 cm long, 6- to 12-flowered; glumes acuminate, about 1 cm long; lemmas glabrous, scabrous, or sometimes pubescent, acuminate, 1.5 cm long, closely overlapping, concealing the short rachilla joints, awnless or with an awn 1-3 mm long, palea two-thirds as long as the lemma. Cultivated in the southern states as a winter forage grass. Escaped from cultivation. Scattered throughout the state. Introduced from South America.

Bromus inermis Leyss. Smooth brome.

Culms erect, 50-100 cm tall, from creeping rhizomes; ligule 1.5-2 mm long; blades smooth or nearly so, 5-10 mm wide; panicle 10-20 cm long, erect, the branches whorled, spreading in flower, contracted at maturity; spikelets 2-2.5 mm long, subterete before flowering; first glume 4-5 mm long, the second 6-8 mm long; lemmas 9-12 mm long, glabrous or somewhat scabrous, rarely villose, obtuse, emarginate, mucronate, or with an awn 1-2 mm long. Cultivated as hay and pasture

grass; along roads and in waste places scattered throughout the state. Introduced from Europe.

Bromus ciliatus L. Fringed brome. Brome grass.

Culms slender, 70-120 cm tall, glabrous or pubescent at the nodes; sheaths glabrous or the lower short-pilose, mostly shorter than the internodes; blades rather lax, as much as 1 cm wide, sparsely pilose on both surfaces to glabrous; panicle 15-25 cm long, open, the branches slender, drooping, as much as 15 cm long; first glume 1-nerved, the second 3-nerved; lemmas 10-12 mm long, pubescent near the margin on the lower half to three-fourths, glabrous or nearly so on the back; awn 3-5 mm long. Moist woods and rocky slopes of Warren, Shenandoah, Montgomery, Wythe and Smyth Counties.

Bromus kalmii A. Gray. Wild chess.

Culms slender, 50-100 cm tall, usually pubescent at and a little below the nodes; sheaths usually shorter than the internodes, pilose or the upper glabrous; blades usually sparsely pilose on both surfaces, 5-10 mm wide; panicle rather few-flowered, drooping, mostly 5-10 cm long, the branches slender, flexuous, bearing usually 1-3 spikelets; first glume 3-nerved, second 5-nerved; lemmas 7-10 mm long, villose over the back, more densely so near the margins; awn 2-3 mm long. Dry or sandy ground and open woods of Augusta, Bath and Highland Counties.

Bromus purgans L. (= *B. pubescens* Muhl. in Willd.). Canada brome.

Resembling *B. ciliatus*; nodes mostly 4-6; sheaths, except the lower 1 or 2, shorter than the internodes, more or less retrosely pilose, or sometimes all glabrous; blades elongate, 5-17 mm wide, narrowed at base, and without flanges or auricles; pubescence of lemma nearly uniform, sometimes more dense on the margins, sometimes sparse and short on the back or scabrous only. Moist woods and rocky slopes throughout the state.

Bromus nottawayanus Fern. No common name known.

Resembling *B. latiglumis*, but with fewer nodes; sheaths mostly longer than the internodes, usually retrosely pilose, without flanges at the mouth; ligule very short; blades elongate, 6-13 mm wide; pilose above, some sparsely so beneath; panicles 12-22 cm long, the slender branches drooping, the pulvini inconspicuous; first glume 1- to 3-nerved, the second 5-nerved; lemma 8-13 mm long, densely appressed-pilose, the awn 5-8 mm long. Rich woods of Greensville and Sussex Counties.

Bromus latiglumis (Shear) Hitchc. No common name known.

Differing from *B. purgens* in having usually 10 to 20 nodes; sheaths overlapping, more or less pilose, especially about the throat and collar; base of blades with prominent flanges on each side, then usually prolonged into auricles. Where the ranges of *B. purgens* and *B. latiglumis* overlap, the latter flowers several weeks later than the former. Alluvial banks of streams of Fairfax, Giles, Shenandoah and Sussex Counties.

Bromus racemosus L. No common name known.

Differing from *B. mollis* in the somewhat more open panicle and glabrous and scabrous lemmas. Weed in waste places throughout the state. Introduced from Europe.

Bromus scoparius L. No common name known.

Culms 20-30 cm tall; sheaths soft-pubescent; blades glabrous, scabrous or sparingly pilose; panicle contracted, erect, 3-7 cm long; spikelets about 1.5 cm long, 3-4 mm wide; lemmas about 7 mm long, narrow, glabrous, awn 5-8 mm long, finally divaricate. Rare. Introduced from Europe on ballast at Newport News.

Bromus mollis L. Soft chess. Soft brome.

Softly pubescent throughout; culms erect, 20-80 cm tall; panicle erect, contracted, 5-10 cm long, or, in depauperate plants, reduced to a few spikelets; glumes broad, obtuse, coarsely pilose or scabrous-pubescent, the first 3- to 5-nerved, 4-6 mm long, the second 5- to 7-nerved, 7-8 mm long; lemmas broad, soft, obtuse, 7-nerved, coarsely pilose or scabrous, pubescent, rather deeply bidentate, 8-9 mm long, the margin and apex hyaline, awn rather stout, 6-9 mm long; palea about three-fourths as long as lemma. Weed in waste places and cultivated soil of Arlington, Fairfax, Montgomery and Prince George Counties. Introduced from Europe.

Bromus secalinus L. Cheatgrass. Rye brome. Chess. Cheat. Smooth chess.

Culms erect, 30-60 cm tall; foliage glabrous or the lower sheaths sometimes puberulent; panicle pyramidal, nodding, 7-12 cm long, the lower branches 3 to 5, unequal, slightly drooping; spikelets ovoid-lanceolate, becoming somewhat turgid at maturity, 1-2 cm long, 6-8 mm wide; glumes obtuse, the first 3- to 5-nerved, 4-6 mm long, the second 7-nerved, 6-7 mm long, elliptic, obtuse, smooth or scaberulous, the margin strongly involute at maturity, shortly bidentate at apex, the undulate awns usually 3-5 mm long, sometimes very short or obsolete; palea about as long as lemma. A weed in grainfields and waste places scattered throughout the state. Introduced from Europe.

Bromus commutatus Schrad. Hairy chess.

Resembling *B. secalinus*, but the sheaths retrorsely pilose; the blades more or less pubescent; lemmas at maturity less plump and more overlapping; awn commonly much longer. A weed in fields and waste places scattered throughout the state. Introduced from Europe.

Bromus japonicus Thunb. Japanese chess. Japanese brome.

Culms erect or geniculate at base, 40-70 cm tall; sheaths and blades pilose; panicle 12-20 cm long, broadly pyramidal, diffuse, somewhat drooping, the slender lower branches 3 to 5, all the branches more or less flexuous; glumes rather broad, the first acute, 3-nerved, 4-6 mm long, the second obtuse, 5-nerved, 6-8 mm long; lemmas broad, obtuse, smooth, 7-9 mm long, 9-nerved, the marginal pair of nerves faint, the hyaline margin obtusely angled above the middle, the apex blunt, emarginate; awn 8-10 mm long, usually somewhat twisted and flexuous at maturity, those of the lower florets shorter than the upper; palea 1.5-2 mm shorter than the lemma. Weed in waste places throughout the state. Introduced from the old world.

Bromus arvensis L. Field brome.

Resembling *B. japonicus*, foliage downy to subglabrous; spikelets thinner, flatter (less turgid), often tinged with purple; lemmas acute, bifid, awn straight or nearly so in drying; palea as long as the lemma or only slightly shorter. A weedy species on open ground, cultivated soil in Isle of Wight, Roanoke and Washington Counties.

Bromus madritensis L. Spanish brome. Compact brome. Madrid brome.

Culms 15-40 cm tall, smooth below the panicles; sheaths mostly smooth, blades puberulent to glabrous; panicle 5-10 cm long, oblong-ovoid (in dried specimens more or less fan shaped); lemmas longer than 16 mm, the teeth 2-3 mm long, awn rather stout, 16-22 mm long. Open ground and waste places, occasionally cultivated for ornament and escaping.

Bromus tectorum L. Downy brome. Drooping brome. Cheatgrass. Downy chess.

Culms erect or spreading, slender, 30-60 cm tall; sheaths and blades pubescent; panicle 5-15 cm long, rather dense, soft, drooping, often purple; spikelets nodding, 12-20 mm long; glumes villose, the first 4-6 mm long, the second, 8-10 mm long; lemmas lanceolate, villose or pilose, 10-12 mm long, the teeth 2-3 mm long, awn 12-14 mm long. Along roadsides, banks and waste places in infertile places, more frequent in the mountains.

Bromus sterilis L. Poverty brome. Barren brome. Sterile brome.

Resembling *B. rigidus*, less robust; culms 50-100 cm tall; sheaths pubescent; panicle 10-20 cm long, the branches drooping; spikelets 2.5-3.5 cm long, 6- to 10-flowered; glumes lanceolate-subulate, the first about 8 mm long; lemmas 17-20 mm long, scabrous or scabrous-pubescent, the teeth 2 mm long, awn 2-3 cm long. Fields and waste places infrequently throughout the state.

Bromus rigidus Rath. Ripgut grass. Ripgut brome.

Culms 40-70 cm tall; sheaths and blades pilose; panicle open, nodding, rather few-flowered, 7-15 cm long, the lower branches 1-2 cm long; spikelets usually 5- to 7-flowered, 3-4 cm long, excluding awns; glumes smooth, the first 1.5-2 cm long, the second 2.5-3 cm long; lemmas 2.5-3 cm long, scabrous or pubescent, the teeth 3-4 mm long, awn stout, 3.5-5 cm long. Open ground and waste places, infrequent in Virginia. Introduced from Mediterranean area.

Buchloe Engelm.

Low stoloniferous perennial with short curly blades; dioecious or monoecious; staminate flowers in 2 or 3 short spikes on slender erect culms, spikelets 2-flowered, sessile; pistillate flowers in sessile heads partly hidden among the leaves.

Buchloe dactyloides (Nutt.) Engelm. Buffalo grass

Plants grey green, the curly blades forming a dense sod 5-10 cm thick; blades rather sparsely pilose, 1-2 mm wide; staminate culms slender, 5-20 cm tall, the spikes 5-15 mm long; pistillate heads 3-4 mm thick. Grounds of Poplar Forest, Bedford County (Ramsey and Brooks, 1987).

Calamagrostis Adans. Reedgrass

Perennial; culms unbranched, tall with running root stocks; panicles many-flowered; spikelets 1-flowered; glumes nearly equal; lemma awned on the back, surrounded at base with many long hairs attached to callus; rachilla disarticulating above glumes, prolonged behind palea as a short, commonly hairy bristle.

1. Awn geniculate, protruding sidewise from glumes; callus hairs rather sparse, shorter than lemma *C. porteri*
 - 1'. Awn straight, included; callus hairs usually not much shorter than lemma 2
 2. Panicle rather loose and open *C. canadensis*
 - 2'. Panicle more or less contracted *C. cinnoides*
- Calamagrostis porteri* A. Gray. No common name known.

Culms slender, 60-120 cm tall, with slender rhizomes; sheaths pubescent on the collar; blades flat, spreading, lax, 4-8 mm wide; panicle narrow but rather loose, erect or somewhat nodding, 10-15 cm long; glumes 4-6 mm long, scaberulous; lemma slightly shorter than the glumes, toothed at apex, the awn from near base, about as long as the lemma, bent and protruding from side of glumes; palea about as long as the lemma; callus hairs in tufts at the sides, rather scant, nearly half as long as the lemma; rachilla hairs scant, extending to about 3 mm. Dry rocky soils among stones and boulders in western part of the state.

Calamagrostis canadensis (Michx.) Beauv. Bluejoint grass. Bluejoint.

Culms suberect, tufted, 60-150 cm tall, with numerous creeping rhizomes; sheaths glabrous or rarely obscurely pubescent; blades numerous, elongate, flat, rather lax, scabrous, 4-8 mm wide; panicle nodding, from narrow and rather dense to loose and relatively open, especially at base, 10-25 cm long; glumes usually 3-4 mm long, smooth or more commonly scabrous, acute to acuminate; lemma nearly as long as the glumes, smooth, thin in texture, the awn delicate, straight, attached just below the middle and extending to or slightly beyond its tip, the callus hairs abundant, about as long as lemma; rachilla delicate, sparsely long-pilose. Marshes and wet places, open woods and meadows of western part of the state.

Calamagrostis cinnoides (Muhl.) Barton. No common name known.

Glaucous culms rather stout, erect, 80-150 cm tall, with slender rhizomes readily broken off; sheaths and blades very scabrous, sometimes sparsely hirsute, the blades flat, 5-10 mm wide; panicle erect, dense, more or less lobed (somewhat open at anthesis), 8-20 cm long, purple-tinged; glumes 6-7 mm long, scabrous, long-acuminate or awn-pointed; lemma firm, acuminate, scabrous, shorter than the glumes, the awn attached about one-fourth below the tip, not much exceeding the lemma, the callus hairs copious, about two-thirds as long; rachilla about 1 mm long, glabrous below, with a brush of long white hairs at the tip about equalling the lemma. Bogs and moist ground throughout the state.

Calamovilfa Hack.

Rigid, usually tall perennials with narrow or open panicles; spikelets 1-flowered, rachilla disarticulating above glumes, not prolonged behind palea; glumes unequal, chartaceous, 1-nerved, acute; lemma a little longer than second glume, chartaceous, 1-nerved, awnless, glabrous or pubescent; callus bearded; palea about as long as lemma.

Calmovilfa brevipilis (Torr.) Scribn. No common name known.

Culms solitary or few, compressed, 60-120 cm tall, the base a short thick horizontal rhizome; blades elongate, 2-3 mm wide, flat to subinvolute; panicle subpyramidal, rather open, 10-25 cm long, the branches ascending, flexuous, naked below; pedicels sparsely pilose at the summit; spikelets brownish, 5-6 mm long, the second about 4 mm long; lemmas villose on the back below, the callus hairs 1.5 mm long; palea exceeding the lemma, villose on the back. Marshes and riverbanks, sphagnum bogs, Brunswick and Greensville Counties.

Cenchrus L. Sandbur.

Annual or perennial; culms, commonly low and branching, may be up to 1 m high; racemes of 1-flowered spikelets, 1-6 together surrounded by ring of rigid spines fused together at base that drops off with them when fruit is ripe.

1. Body of bur ovate, usually not more than 3.5 mm wide,

tapering at base; plants perennial *C. incertus*

- 1'. Body of bur globose, 5 mm or more wide, root not tapering at base; plants annual 2
2. Burs including spines, 7-8 mm wide, finely pubescent . . . *C. pauciflorus*
- 2'. Burs including spines, 10-15 mm wide, densely woolly . . . *C. tribuloides*

Cenchrus incertus M. A. Curtis. Field sandbur. Burgrass. Coast sandbur.

Perennial, glabrous as a whole; culms 25-100 cm tall; blades commonly folded but sometimes flat, 2-5 mm wide; raceme 4-10 cm long, the burs not crowded; burs about 3.5 (3-5) mm wide, the body finely and densely pubescent, the base glabrous; spines few, mostly less than 5 mm long, the lower often reduced or obsolete; spikelets 1 to 3 in each bur. Open sandy soil of Coastal Plain.

Cenchrus pauciflorus Benth. (= *C. longispinus* (Hack.) Fern.). Field sandbur. Longspine sandbur.

Annual, at times a short-lived perennial, sometimes forming large mats; culms spreading, 20-90 cm long, rather stout; blades usually flat, 2-7 mm wide; raceme usually 3-8 cm long, the burs somewhat crowded; burs (excluding spines) mostly 4-6 mm wide, pubescent, often densely so; spines numerous, spreading or reflexed, flat, broadened at base, the lowermost shorter and relatively slender, some of the upper ones commonly 4-5 mm long, usually villose at the base; spikelets usually 2 in each bur. Sandy open ground, often a weed in sandy fields scattered throughout the state.

Cenchrus tribuloides L. Dune sandbur.

Stouter than *C. pauciflorus*; soon branching and radiate-decumbent, rooting at the nodes; sheaths usually much overlapping; burs (excluding spines) 5-6 mm wide and 8-9 mm high, usually conspicuously villose. In loose sands of the Coastal Plain, also Rockbridge County.

Chloris Swartz. Fingergrass

Tufted plants with flat or folded scabrous blades and 2 to several, sometimes showy and feathery, spikes aggregate at the summit of culms; spikelets with 1 rudimentary floret and 1 perfect floret, sessile, in 2 rows along one side of a continuous rachis; glumes somewhat unequal, the first shorter, narrow, acute; lemma keeled, usually broad.

1. Rudiment truncate-broadened at apex, usually conspicuous *C. verticillata*
- 1'. Rudiment narrow, oblong, acute, often inconspicuous . . . 2
2. Plant producing long stout stolons; culms 1-1.5 m tall . . . *C. gayana*
- 2'. Culms straggling and rooting at nodes, 40-90 cm tall . . . *C. ventricosa*

Chloris verticillata Nutt. Windmill grass.

Culms tufted, 10-40 cm tall, erect or decumbent at base, sometimes rooting at lower nodes; leaves crowded at base, 2 to 4, sometimes aggregate at lower nodes, sheath compressed, blades 1-3 mm wide, obtuse; spikes slender, 7-10 (-15) cm long, in 1 to 3 whorls, finally widely spreading; spikelets about 3 mm long; fertile lemma pubescent on nerves, awn mostly 5-8 mm long; rudiment (rarely fertile) cuneate-oblong, rather turgid, about 0.7 mm wide as folded, truncate, the awn about 5 mm long. Roanoke, Augusta and Frederick Counties, probably introduced from Plains States.

Chloris gayana Kunth. Rhodesgrass. Rhodes grass.

Culms 1-1.5 m tall with long, stout, leafy stolons, the internodes compressed, tough and wiry; blades 3-5 mm wide, tapering to a fine point; spikes several to numerous, erect or ascending, 5-10 cm long; spikelets crowded, pale-tawny; lemma 3 mm long, hispid on the margin near the summit, more or less hispidulous below, the awn 1-5 mm long; rudiment commonly of 2 florets, the lower occasionally fertile, rather narrow, the awn usually somewhat shorter than that of the fertile lemma, the upper minute, broad, truncate. Cultivated for forage, escaped into fields and waste places. Introduced from Africa.

Chloris ventricosa R. Br. No common name known.

Culms straggling and rooting at the nodes, 40-90 cm long; spikes 3 to 5, 7-10 cm long, flexuous, spreading or drooping; spikelets about 5 mm long; fertile lemma subindurate, brown, truncate, glabrous except for the pubescent callus, awn 4-5 mm long, that of the truncate rudiment 1-2 mm long. Occasionally cultivated, rare in the state. Introduced from Australia.

Cinna L. Woodreed

Tall perennials; panicles many-flowered, nodding; spikelets 1-flowered; glumes narrow, with short, stiff hairs on keel; lemma with short awn between the two small teeth at the tip; palea with only one keel; rachilla extending beyond palea into a tiny bristle.

- 1. Spikelets 5 mm long; panicle rather dense, branches ascending *C. arundinacea*
- 1'. Spikelets 3.5-4 mm long; panicle loose, branches spreading or drooping *C. latifolia*

Cinna arundinacea L. Woodreed grass. Stout woodreed.

Culms erect, usually 1-1.5 m tall, often somewhat bulbous at base, solitary or few in a tuft; sheaths glabrous, ligule rather prominent, thin; blades flat, scabrous, mostly less than 1 cm wide; panicle many-flowered, nodding, grayish, 15-30 cm long, the branches ascending; spikelets 5-6 mm long; glumes somewhat unequal, acute, the second 3-nerved; lemma usually a little longer than the first glume, bearing below the tip a minute straight awn; palea apparently 1-nerved. Moist woods and swampy areas throughout the state.

Cinna latifolia (Trevir.) Griseb. Drooping woodreed. Broadleaved woodreed.

Resembling *C. arundinacea*; blades shorter and on the average wider, as much as 1.5 cm wide; panicle green, looser, the branches fewer, spreading or drooping, naked at the base for as much as 5 cm; spikelets about 4 mm long; awn of lemma sometimes as much as 1 mm long (rarely wanting); palea 2-nerved, the nerves very close together. Moist woods of Highland, Grayson and Wythe Counties.

Cortaderia Stapf. Pampasgrass.

Large tussock grasses with leaves crowded at the base, blades elongate-atenuate, the margins usually serrulate; panicle large, plumelike, spikelets several-flowered; rachilla internodes jointed, the lower part glabrous, the upper part bearded forming a stipe to the floret; lemmas of pistillate spikelets clothed with long hairs.

Cortaderia selloana (Schult.). Aschers. and Graebn. Pampasgrass.

Dioecious perennial reed, in large bunches; culms stout, erect, 2 to 3 or more m tall; panicle feathery, silvery white to pink, 30-100 cm long; spikelets 2- to 3-flowered, the pistillate silky with long hairs, the staminate naked; glumes white,

papery, long, slender; lemmas bearing a long slender awn. Cultivated as a lawn ornamental in Coastal Plain and eastern Piedmont. Introduced from South America.

Ctenium Panzer

Erect, slender, rather tall perennials with usually solitary, often curved spikes, spikelets several-flowered but with only 1 perfect floret, sessile and pectinately arranged on one side of a continuous rachis, the rachilla disarticulating above the glumes; first glume small, hyaline, 1-nerved, the second about as long as the lemmas, firm, 3- to 4-nerved, bearing on the back a strong divergent awn; lemmas rather papery, 3-nerved, with long hairs on the lateral nerves and a short straight or curved awn on the back just below the apex, the first and second lemmas empty, the third enclosing a perfect flower, the upper 1 to 3 empty and successively smaller.

Ctenium aromaticum (Walt.) Wood. Toothache grass. Orange grass.

Culms 1-1.5 m tall, the old sheaths persistent and fibrillose at base; ligule about 1 mm long; blades flat or involute, stiff; spike 5-15 cm long; spikelets 5-7 mm long. Wet pine barrens of Coastal Plain.

Cynodon Rich.

Perennial, usually low grasses with creeping stolons or rhizomes, short blades, and several slender spikes digitate at summit of upright culms; spikelets 1-flowered, awnless, sessile in 2 rows along one side of a slender continuous rachis and appressed to it, rachilla disarticulating above glumes and prolonged behind palea as a slender naked bristle, sometimes bearing a rudimentary lemma; glumes narrow, acuminate, 1-nerved, about equal, shorter than florets; lemma firm, strongly compressed, pubescent on keel, 3-nerved, lateral nerves close to margins.

Cynodon dactylon (L.) Pers. Bermudagrass. Devilgrass. Wiregrass. Common bermudagrass. Scutch grass.

Extensively creeping by scaly rhizomes or by strong flat stolons, the old bladeless sheaths of the stolon and the lowest one of the branches often forming conspicuous pairs of "dog's teeth"; flowering culms flattened, usually erect or ascending, 10-40 cm tall; ligule a conspicuous ring of white hairs; blades flat, glabrous or pilose on the upper surface, those of the innovations often conspicuously distichous; spikes usually 4 or 5, 2.5-5 cm long; spikelets imbricate, 2 mm long, the lemma boat-shaped, acute. Open ground, grassland, fields and waste places scattered throughout the state.

Cynosurus L. Dogtail.

Annuals or perennials with narrow flat blades and dense spikelike or subcapitate panicles; spikelets of two kinds, sterile and fertile together, the fertile one sessile, nearly covered by the short-pedicel sterile one, these pairs imbricate in a dense 1-sided spikelike panicle; sterile spikelets consisting of 2 glumes and several narrow, acuminate, 1-nerved lemmas on a continuous rachilla; fertile spikelets 2- or 3-flowered, the glumes narrow, the lemmas broader, rounded on the back, awn-tipped, the rachilla disarticulating above the glumes.

1. Plants perennial; panicles narrow, spikelike; awns inconspicuous *C. cristatus*
 - 1'. Plants annual; panicles subcapitate; awns conspicuous . . . *C. echinatus*
- Cynosurus cristatus* L. Crested dogtail.

Perennial; culms tufted or geniculate at base, erect, 30-60 cm tall; panicle spikelike, linear, more or less curved, 3-8 cm long; pairs of spikelets about 5 mm long; lemmas with awns mostly not more than 1 mm long. Fields and waste places of the Coastal Plain. Introduced from Europe.

Cynosurus echinatus L. Rough dogtail.

Annual; culms 20-40 cm tall; blades short; panicle subcapitate, 1-4 cm long, bristly; pairs of spikelets 7-10 mm long; lemmas with awns 5-10 mm long. Open ground in Coastal Plain. Introduced from Europe.

Dactylis L. Orchard grass.

Perennials with flat blades and fascicled spikelets; spikelets few-flowered, compressed, finally disarticulating between florets, nearly sessile in dense, 1-sided fascicles, these borne at the ends of the few branches of a panicle; glumes unequal, carinate, acute, hispid-ciliate on the keel; lemmas compressed-keeled, mucronate, 5-nerved, ciliate on keel.

Dactylis glomerata L. Orchard grass. Cocksfoot.

Culms in large tussocks, 60-120 cm tall; blades elongate, 2-8 mm wide; panicles 5-20 cm long, the few distant stiff solitary branches ascending or spreading at anthesis, appressed at maturity, the lowermost sometimes as much as 10 cm long; lemmas about 8 mm long, mucronate or short-awned. Fields, meadows and waste places, commonly cultivated as a meadow and pasture grass throughout the state.

Dactyloctenium Willd.

Annuals or perennials with flat blades and 2 to several short thick spikes, digitate and widely spreading at the summit of the culms; spikelets 3- to 5-flowered, compressed, sessile and closely imbricate, in two rows along one side of the rather narrow flat rachis, the end projecting in a point beyond the spikelets; rachilla disarticulating above the first glume and between the florets; glumes somewhat unequal, broad, 1-nerved, the first persistent upon the rachis, the second mucronate or short-awned below the tip, deciduous; lemmas firm, broad, keeled, acuminate or short-awned, 3-nerved, the lateral nerves indistinct, the upper floret reduced; palea about as long as lemma.

Dactyloctenium aegyptium (L.) Beauv. Crowfoot grass.

Culms compressed, spreading with ascending ends, rooting at nodes, branching, commonly forming radiate mats, usually 20-40 cm long, sometimes as much as 1 m; blades flat, ciliate; spikes 1-5 cm long. Open ground, waste places and fields, Norfolk, Isle of Wight. Introduced from Old World Tropics.

Danthonia Lam. and DC. Oatgrass.

Tufted low or moderately tall perennials; panicles few-flowered, open or spikelike; spikelets large, 1- or 2-flowered, cleistogamous, in lower sheaths; glumes about equal, mostly exceeding uppermost floret; lemmas rounded on back, apex bifid, lobes acute, usually extending into slender awns, a stout geniculate awn arising from between the lobes.

- 1. Sheaths pilose; spikelets 2-6 *D. sericea*
- 1'. Sheaths glabrous; spikelets 1 or 2 2
- 2. Panicle simple or nearly so, usually contracted after anthesis; blades rarely more than 15 cm long, commonly less; teeth of lemma triangular *D. spicata*
- 2'. Panicle usually compound and somewhat open; blades

to 25 cm long; teeth of lemma long bristles *D. compressa*
Danthonia sericea Nutt. Downy oatgrass.

Culms erect, densely tufted, 50-100 cm tall; sheaths, especially the lower, pilose (rarely glabrous); blades 10-25 cm long, 2-4 mm wide, those of the innovations mostly involute, those of the culm mostly flat; panicle 5-10 cm long, relatively many-flowered, the branches bearing 2 to 6 spikelets, rather open or contracted after anthesis; glumes 12-17 mm long; lemmas densely long-pilose, especially along the margin, about 10 mm long, including the slender aristate teeth, the teeth about half the entire length; palea concave, narrowed toward the 2-toothed apex. Sand barrens in the Coastal Plain but scattered through the western part of the state.

Danthonia spicata (L.) Beauv. ex Roem. and Schult. Poverty oatgrass.

Poverty grass.

Culms 20-70 cm tall, mostly not more than 50 cm, slender, terete; leaves numerous in a basal cluster, the blades usually curled or flexuous, sheaths glabrous or pilose above the nodes, with a tuft of long hairs in the throat; blades usually not more than 12 cm long, filiform, to 2 cm wide, occasionally a few blades 15-20 cm long, subinvolute or in damp weather flat, glabrous or sparsely pilose; panicle 2-5 cm long, rarely longer, the stiff short branches bearing a single spikelet, or the lower longer with 2 (rarely 3 or 4), usually erect after anthesis; glumes 10-12 mm long (rarely longer); lemmas 3.5-5 mm long, sparsely villose except the 2-toothed summit, the teeth acuminate to subsetaceous; terminal segment of the awn about 5 mm long; palea broad, flat, obtuse, ciliate, reaching to the base of the awn. Dry and sterile or rocky soil throughout the state.

Danthonia compressa Austin. Mountain oatgrass.

Culms on the average stouter and taller than in *D. spicata*, compressed, rather loosely tufted, sometimes decumbent or with short rhizomes, 40-80 cm tall; sheaths reddish above nodes, glabrous or sparsely pubescent on the collar, a conspicuous tuft of white hairs in the throat; blades elongate, some of them commonly 20-25 cm long, 2-3 mm wide, usually flat, sometimes involute and subfiliform, scabrous; panicle 5-8 cm long (rarely to 10 cm), the slender branches bearing 2 or 3 spikelets, contracted after anthesis but looser than in *D. spicata*; glumes 10-14 mm (usually about 12 mm) long; lemma and palea as in *D. spicata* but the teeth of the lemma aristate, 2-3 mm long. Meadows, open woods, open fields and woodland trails, common in the mountains but also in Brunswick and Surry Counties.

Deschampsia Beauv. Hairgrass.

Low or moderately tall perennials; panicles narrow or open; spikelets 2-flowered, disarticulating above glumes and between florets; glumes about equal, acute or acutish; lemmas truncate, 2- to 4-toothed at apex, bearded at base, with slender, straight, bent or twisted awn from or below the middle.

1. Blades filiform, flexuous; awn exerted, geniculate,
 twisted *D. flexuosa*

1'. Blades flat or folded, stiff; awn included or slightly
 exerted, straight *D. caespitosa*

Deschampsia flexuosa (L.) Trin. Crinkled hairgrass. Hairgrass.

Culms densely tufted, erect, slender, 30-80 cm tall; leaves mostly in a basal tuft, numerous, the sheaths scabrous, the blades involute, slender or setaceous, flexuous; panicle loose, open, nodding, 5-12 cm long, the capillary branches naked below,

the branchlets spikelet-bearing toward the ends; spikelets 4-5 mm long, purplish or bronze, the florets approximate; lemmas scabrous, the callus hairs about 1 mm long, the awn attached near the base, geniculate, twisted, 5-7 mm long. Dry or rocky woods, slopes and open ground scattered throughout the state.

Deschampsia caespitosa (L.) Beauv. Tufted hairgrass.

Culms in dense tufts, leafy at base, erect, 60-120 cm tall; sheaths smooth; blades 1.5-4 mm wide, often elongate, rather firm, flat or folded, scabrous above; panicle loose, open, nodding, 10-25 cm long, the capillary scabrous branches and branchlets spikelet-bearing toward the ends, spikelets 4-5 mm long, pale or purple-tinged, the florets distant, the rachilla internode half the length of the lower floret; glumes 1-nerved or the second obscurely 3-nerved, acute, about as long as the florets; lemmas smooth, the callus hairs short, awn from near the base, from straight and included to weakly geniculate and twice as long as the spikelet. Bogs and wet places of Giles and Page Counties.

Diarrhena Beauv.

Perennials with slender rhizomes, broadly linear, flat blades, long-tapering below and narrow few-flowered panicles; spikelets few-flowered, the rachilla disarticulating above the glumes and between the florets; glumes unequal, acute, shorter than the lemmas, the first 1-nerved, the second 3- to 5-nerved; lemmas chartaceous, pointed, 3-nerved, the nerves converging in the point, the upper floret reduced; palea chartaceous, obtuse, at maturity the lemma and palea widely spread by the large turgid beaked caryopsis with hard shiny pericarp.

Diarrhena americana Beauv. Twin grass.

Culms slender, about 1 m tall, arched-leaning, leaves approximate below the middle of the culm; sheaths pubescent toward the summit; blades elongate, 1-2 cm wide, scabrous to pubescent beneath; panicle long-exserted, drooping, 10-30 cm long, the branches few, appressed, the lower distant; spikelets 10-18 mm long, at first narrow, the florets expanded at maturity; lemmas 6-10 mm long. Rich or moist woods of Carroll, Patrick and Russell Counties.

Dichanthelium (Hitchc. & Chase) Gould.

Perennials, typically tufted and usually forming in late summer or early fall a basal rosette of blades shorter and broader than those of the culms; culms stiffly erect or decumbent-erect, glabrous or hairy, 15-70 cm tall, infrequently to 150 cm or more tall; sheaths of main culms rounded on the back, often shorter than the culm internodes, glabrous or variously hairy; ligule usually a ring of hairs, infrequently a short membrane or absent; culm blades narrow or broad, usually flat, the reduced blades of secondary branches involute in some species; secondary branching after the first culm growth and elongation often resulting in densely clustered fascicles of often much-reduced leaves and inflorescences; inflorescence typically a small panicle with spreading or occasionally contracted branches, the spikelets short- or long-pedicel, ovate, elliptical or obovate, awnless, 0.8-4.5 mm long, disarticulation below glumes; glumes both present, but the lower one often greatly reduced; first glume nerved or nerveless, mostly $1/4$ to $1/3$ as long as the spikelet but minute in a few species and $3/4$ the length of the spikelet in others; lower floret usually neuter but staminate in a few species; upper floret perfect, with a shiny, glabrous, coriaceous lemma and palea, the lemma tightly inrolled over the palea; palea apex rounded, with minute symmetrical papillae in longitudinal rows and in

apical ridge with 7-12 large stomata in one or more rows (Brown and Smith, 1975; Gould and Clark, 1978).

1. Branches elongate, not more than 5 mm wide, 20 times as long as wide; autumnal phase branching from the base only 2
- 1'. Branches not elongate or, if so, more than 5 mm wide; autumnal phase not branching from the base 3
2. Spikelets about 3.1-4.5 mm long, beaked *D. depauperatum*
- 2'. Spikelets 2.2-3(3.2) long, not beaked *D. linearifolium*
3. Plants branching from the base, finally forming rosettes or cushions, the foliage soft, lax, similar to and only slightly shorter than culm blades 4
- 3'. Plants branching from the culm nodes or rarely remaining simple; basal rosette of short relatively broad, firm or thin blades usually conspicuously shorter than culm blades 5
4. Sheaths retrorsely pilose, uppermost at least 3/4 as long as those of basal tuft; blade margins glabrous or finely ciliate *D. laxiflorum*
- 4'. Sheaths glabrous or ascending-pilose; uppermost culm blade 1.5-6 cm long, less than 3/4 as long as those of basal tuft; blade margins coarsely papillose-ciliate *D. leucoblepharis*
5. Spikelets 3.3-5.2 mm long 6
- 5'. Spikelets 0.8-3.2 mm long 12
6. Blades of culm leaves, at least some, 1.3-3.5 cm broad . . . 7
- 6'. Blades of culm leaves 1.2 cm or less broad 11
7. Spikelets broadly elliptic to obovate, turgid, usually with broad heavy nerves *D. oligosanthos*
- 7'. Spikelets narrowly elliptic to obovate, not turgid or strongly nerved 8
8. Culm nodes, at least the lowermost, bearded; spikelets 3.8-5.2 mm long 9
- 8'. Culm nodes glabrous or slightly pubescent; spikelets 3.3-3.8 mm long 10
9. Ligules up to 1.5 mm long; blades glabrous or puberulent; spikelets 4-5.2 mm long *D. boscii*
- 9'. Ligules 2.5-4 mm long; blades commonly puberulent-tomentose on one or both surfaces but occasionally nearly glabrous; spikelets 3.8-4.2 mm long *D. ravenelii*
10. Sheaths glabrous or softly villose; blades mostly 8-12 (-18) cm long *D. latifolium*
- 10'. Sheaths, at least the lower ones, papillose-hispid with spreading hairs; blades 10-28 cm long *D. clandestinum*
11. Midculm blades firm and stiff, long-acuminate at apex; lower culm internodes glabrous or hairy but not puberulent; spikelets 3.3-3.6 mm long *D. aciculare*
- 11'. Midculm blades thin or firm, not long-acuminate at apex;

- lower culm internodes various; spikelets 3.3-3.9 mm long . . . *D. sabulorum*
12. Blades of primary culms, at least some, 1.3-2.5 cm broad . . . 13
- 12'. Blades of primary culms up to 1.2 cm broad 16
13. Culm nodes, at least the lower ones, bearded, the lower internodes with long spreading hairs; glabrous-glandular band absent below culm nodes *D. scoparium*
- 13'. Culm nodes glabrous or slightly hairy, internodes typically glabrous-glandular 14
14. Lower blades cordate at base; ligule absent or a ring of hairs; spikelets 2.1-2.9 mm long 15
- 14'. Blades not cordate at base; ligule a fringed or glabrous membrane; spikelets 2.2-2.9 mm long *D. scabriusculum*
15. Spikelets (2.1-) 2.4-3.2 mm long, narrowly ovate or elliptic *D. commutatum*
- 15'. Spikelets 2.1-2.2 mm long, broadly elliptic to suborbicular *D. sphaerocarpon*
16. Blades, at least the lower ones, cordate or subcordate at base, mostly 6-12 mm broad *D. boreale*
- 16'. Blades not cordate nor subcordate at base, narrow or broad 17
17. Hairs of ligule or pseudoligule, at least some, 2-5 mm long 18
- 17'. Hairs of ligule or pseudoligule less than 2 mm long 19
18. Ligule with a dense ring of short hairs in front of a thin line of long hairs *D. ovale*
- 18'. Ligule without a dense ring of short hairs in front of line of long hairs *D. acuminatum*
19. Culm internodes glabrous or the lower ones slightly pilose; culm nodes bearded with long spreading hairs; blade surfaces glabrous or those of the lower leaves slightly pilose *D. dichotomum*
- 19'. Culm internodes, at least the lower ones, strigose or villose; culm nodes bearded with spreading or appressed hairs; blade surfaces glabrous or variously hairy *D. consanguineum*
- Dichanthelium depauperatum* (Muhl.) Gould. Starved panic
- Basionym: *Panicum depauperatum* Muhl.

Vernal phase with culms several to many in a tuft, slender but rather stiff, erect or nearly so; sheaths glabrous or papillose-pilose; blades 6-15 cm long, 2-5 mm wide, often involute in drying; panicle exserted, usually not much exceeding the leaves, 4-8 cm long, few-flowered; spikelets 3.2-3.8 mm long, elliptic, pointed, glabrous or sparsely pubescent; second glume and sterile lemma extending beyond the fruit, forming a beak. Autumnal phase similar, the reduced panicles concealed in basal leaves. Open sterile woods throughout the state.

Dichanthelium linearifolium (Scribn.) Gould. Low panic grass

Basionym: *Panicum linearifolium* Scribn.

Synonym: *Panicum wernerii* Scribn.

Vernal phase in dense tufts; culms slender, erect, 20-45 cm tall; sheaths papillose-pilose; blades erect, usually overtopping the panicles, 2-4 mm wide; panicle long-exserted, 5-10 cm long, the flexuous branches ascending; spikelets 2.2-2.7 mm

long, oblong-elliptic, obtuse, sparsely pilose. Autumnal phase similar, the reduced panicles hidden among basal leaves. Dry woods scattered in northwestern part of state and Tidewater area.

Dichanthelium laxiflorum (Lam.) Gould. Loose-flowered panic.

Basionym: *Panicum laxiflorum* Lamarck.

Synonym: *Panicum xalapense* H.B.K.

Vernal culms 20-60 cm tall, erect or geniculate below; nodes bearded with reflexed hairs; sheaths retrorsely pilose; blades 10-20 cm long, 7-12 mm wide, glabrous or sparsely ciliate; panicle 8-12 cm long, lax, few-flowered, the lower branches often reflexed; spikelets 2.2-2.3 mm long, papillose-pilose. Autumnal blades scarcely reduced, much exceeding the secondary panicles. Rich or damp woods scattered throughout the state.

Dichanthelium leucoblepharis (Trin.) Gould and Clark. No common name known.

Basionym: *Panicum leucoblepharis* Trin.

Synonym: *Panicum strigosum* Muhl.

Plants densely tufted, with leaves mostly in a basal tuft; culms 5-35 cm tall, not branching above base, sheaths glabrous or pilose, most frequently hairy on margins; ligule a minute fringe of hairs much less than 1 mm long; blades typically short and broad, mostly 3-6 cm long and 3-8 mm broad, usually coarsely ciliate with stiff, papilla-based hairs to well above middle, uppermost leaf blade usually much shorter than those below; panicles open, few-flowered, mostly 3-5 cm long, scarcely elevated above basal tuft of leaves or well-exserted on long peduncles; panicle axis usually pilose with spreading hairs; spikelets 1.1-2.1 mm long, glabrous to pubescent or puberulent, elliptic or slightly obovate, broadly pointed or rounded at apex; first glume broadly pointed or rounded at apex, one-third to half as long as spikelet; second glume and lemma usually 7-nerved. In shaded to somewhat open areas of pine forest mostly in sandy acidic soils of Dinwiddie and Prince George Counties and City of Norfolk.

Dichanthelium oligosanthes (Schultes) Gould. Few-flowered panic.

Basionym: *Panicum oligosanthes* Schultes.

Synonym: *Panicum scribnerianum* Nash.

Vernal culms 35-80 cm tall, appressed-pubescent, especially below; sheaths with ascending papillose pubescence; blades stiffly spreading or ascending, 6-14 cm long, 5-8 mm wide, glabrous or nearly so on upper surface, harshly puberulent beneath; panicle 6-12 cm long; spikelets long-pedicel, 3.5-4 mm long, subacute, sparsely hirsute. Autumnal phase erect to spreading, branching freely from upper nodes. Sandy, usually moist woods scattered throughout the state.

Dichanthelium boscii (Poir.) Gould & Clark. No common name known.

Basionym: *Panicum boscii* Poir.

Culms stout, few to several in small clumps, 40-70 cm tall, in age branching above and often becoming top heavy and reclining; internodes glabrous, puberulent or papillose; nodes retrorsely bearded; sheaths glabrous, puberulent or papillose-pilose; ligule a fringe of hairs ca. 1 mm long; blades glabrous to pubescent or villose on one or both surfaces, 7-12 cm long, 15-30 mm broad, often asymmetrical, sparsely ciliate at the usually broad cordate base; panicles 4-10 cm long, to 8 cm broad, with stiffly erect-spreading, usually puberulent branches; spikelets papillose-pubescent,

narrowly ellipsoid to ovate, (3.7-) 4-5.2 mm long; first glume one-third to two-thirds the length of spikelet; lower floret often staminate. In shaded, well-drained forest sites scattered throughout the state.

Dichanthelium ravenellii (Scribn. & Merr.) Gould. No common name known.

Basionym: *Panicum ravenellii* Scribn. & Merr.

Vernal culms 30-70 cm tall, densely papillose-hirsute with ascending hairs, the nodes short-bearded; sheaths hirsute like culm; ligule 3-4 mm long; blades thick, 8-15 cm long, 1-2 cm wide, glabrous on upper surface, densely velvety-hirsute beneath; panicle 7-12 cm long; spikelets 4.3 mm long, sparsely papillose-pubescent. Autumnal phase more or less spreading, branching from middle and upper nodes, the short branches crowded at summit. Sandy or gravelly woods or open ground throughout the state.

Dichanthelium latifolium (L.) Harvill. Broad-leafed panic.

Basionym: *Panicum latifolium* L.

Synonym: *Dichanthelium latifolium* (L.) Gould & Clark.

Vernal culms from a knotted crown; culms 45-100 cm tall, glabrous or lower part sparsely pubescent; sheaths ciliate; blades 8-18 cm long, 1.5-4 cm wide, glabrous; panicle 7-15 cm long; spikelets 3.4-3.7 mm long. Autumnal culms more or less spreading, branching from the middle nodes, upper leaves of branches crowded and spreading, not much reduced. Rocky or sandy woods in western counties and also cities of Virginia Beach and Norfolk.

Dichanthelium clandestinum (L.) Gould. Deer tongue.

Basionym: *Panicum clandestinum* L.

Vernal culms in large dense clumps, sometimes with strong rhizomes, 5-10 cm long, scabrous to papillose-hispid, at least below the nodes, 70-150 cm tall; sheaths strongly papillose-hispid to nearly glabrous; blades spreading or finally reflexed, 10-20 cm long, 1.2-3 cm wide, scabrous on both surfaces, at least toward the end, usually ciliate at base; panicle 8-15 cm long; spikelets 2.7-3 mm long. Autumnal culms erect or leaning, the branches leafy, the swollen bristly sheaths overlapping and wholly or partially enclosing the panicles. Moist mostly sandy ground throughout the state.

Dichanthelium aciculare (Desv. ex Poir.) Gould & Clark. Narrow-leaved panic.

Basionym: *Panicum aciculare* Desva. ex Poir.

Synonyms: *Dichanthelium angustifolium* (Ell.) Gould; *Dichanthelium fusiforme* (Hitchc.) Harvill; *Panicum angustifolium* Ell.; *Panicum fusiforme* Hitchc.

Vernal culms ascending from a spreading base, 20-50 cm tall, appressed-pubescent below; lower sheaths villous; blades spreading or ascending, narrowed to an involute point, glabrous or the lower sparsely pilose, the middle culm blades 4-6 cm long, 2-5 mm wide; panicles 3-7 cm long, the flexuous branches spreading at maturity; spikelets 1.8-2 mm long, obovate. Autumnal phase bushy branching, the culms 10-30 cm long, spreading, forming dense cushions, the blades involute, sharp-pointed, usually arcuate, mostly 1-3 cm long. Sandy pine woods of Coastal Plain.

Dichanthelium sabulorum (Lam.) Gould and Clark. American panic.

Basionym: *Panicum sabulorum* Lam.

Synonyms: *Panicum columbianum* Scribn; *Panicum oricola* Hitchc. & Chase; *Panicum patulum* (Scribn & Merr.) Hitchc.; *Panicum tsugetorum* Nash; *Panicum lanciarum* Trin.

Culms erect or trailing at the base, often much branched, 15-60 cm tall, usually with numerous nodes and short internodes, at least the lowermost minutely puberulent to short-pubescent, rarely glabrous; leaves typically glabrous on the surfaces and glabrous or pubescent on upper sheath margins, often coarsely ciliate on blade margins at and occasionally above the base; ligule a ring of hairs 0.2-1 (-1.5) mm long; blades thin, lanceolate, glabrous or puberulent, never with long hairs except for the marginal cilia, mostly 3-9 cm long and 3-8(-12) mm broad; panicles 3-9 cm long, typically open in age and occasionally with reflexed branches; spikelets puberulent to glabrous, 1.8-3.6 mm long, elliptic or slightly obovate, broadly rounded at apex; first glume broad or narrow, pointed, usually one-third or less as long as spikelet. Autumnal culms more freely branching, often forming large mats. In moist sand of woodland borders of Arlington, Augusta, Fauquier, Lee, Montgomery, Patrick, Prince William and Westmoreland Counties and Cities of Norfolk and Virginia Beach.

Dichanthelium scoparium (Lam.) Gould. No common name known.

Basionym: *Panicum scoparium* Lam.

Vernal phase grayish olive green, velvety-pubescent throughout except on a viscid ring below nodes and at summit of sheath; culms 80-130 cm tall, stout, erect or ascending, usually geniculate at the base; blades rather thick, 12-20 cm long, 10-18 mm wide; panicle 8-15 cm long, the axis and branches with viscid blotches; spikelets 2.4-2.6 mm long, obovate, turgid, papillose-pubescent. Autumnal phase leaning or spreading, freely branching from middle nodes, forming flabellate fascicles. Wet or damp soil mostly in eastern part of the state although scattered through the western part.

Dichanthelium scabriusculum (Ell.) Gould & Clark. No common name known.

Basionym: *Panicum scabriusculum* Ell.

Synonyms: *Panicum cryptanthum* Ashe.; *Panicum aculeatum* Hitchc. & Chase.

Vernal phase grayish olive green; culms erect, 1-1.5 m tall, scabrous at least below the nodes, sometimes puberulent; sheaths glabrous or more or less hispid at least toward summit, often mottled or white spotted, commonly swollen at base and contracted toward summit; blades stiffly ascending or spreading, often reflexed, 15-25 cm long, 9-12 mm wide, glabrous or scabrous, often more or less pubescent beneath; panicle 10-20 cm long; spikelets 2.3-2.6 mm long, ovate, glabrous or obscurely puberulent. Autumnal culms erect, branching from the middle and upper nodes, the branches appressed, finally forming dense oblong masses along the upper part of the primary culm, the panicles partly or entirely enclosed in the sheaths. Moist ground, especially along ditches, streams and swamps of Southampton and Arlington Counties. Harvill *et al.* list *D. scabriusculum* as a synonym of *D. scoparium*. Gould and Clark do not.

Dichanthelium commutatum (Schult.) Gould & Clark. Variable panic.

Basionym: *Panicum commutatum* Schult.

Synonyms: *Panicum joorii* Vasey; *Panicum ashei* Pearson. *Panicum mutabile* Scribn. & Smith ex Nash.

Vernal culms 40-75 cm tall, erect; sheaths glabrous or nearly so; blades 5-12 cm long, 12-25 mm wide, glabrous on both surfaces or puberulent beneath; panicle 6-12 cm long; spikelets 2.6-2.8 mm long. Autumnal culms erect or leaning, branching from the nodes, the secondary branches crowded toward the summit. Woods and coves throughout the state.

Dichanthelium sphaerocarpon (Ell.) Gould. Round-fruited panic.

Basionym: *Panicum sphaerocarpon* Ell.

Synonyms: *Panicum microcarpon* Ell.; *Panicum polyanthes* Schult.

Vernal phase light green; culms 20-80 cm tall, radiate-spreading, sometimes nearly erect, the nodes appressed-pubescent; blades 7-14 mm wide; panicle 5-10 cm long, about as wide; spikelets 1.6-1.8 mm long. Autumnal phase prostrate-spreading, sparingly branched late in the season from the lower and middle nodes, the branches short, mostly simple. Sandy soil throughout the state.

Dichanthelium boreale (Nash) Freckmann. Northern panic.

Basionym: *Panicum boreale* Nash.

Synonym: *Panicum bicknellii* Nash.

Vernal culms usually erect, 30-50 cm tall, nodes mostly glabrous; blades erect or sometimes spreading, 7-12 mm wide, sparsely ciliate at rounded base; panicle loosely rather few-flowered, 5-10 cm long; spikelets 2-2.2 mm long, elliptic, pubescent. Autumnal phase erect or leaning, sparingly branched from all nodes in late summer, the branches erect, leaves and panicles not greatly reduced. Moist open ground or woods, Fairfax County.

Dichanthelium ovale (Ell.) Gould & Clark.

Basionym: *Panicum ovale* Ell.

Synonyms: *Panicum addisonii* Nash; *Panicum mundum* Fernald; *Panicum commonsianum* Ashe.

Vernal culms 20-50 cm tall, erect or ascending, rather stout, long-pilose below with ascending or appressed hairs, often nearly glabrous above, nodes bearded, sheaths ascending-pilose; ligule 2-3 mm long, rather sparse; blades 5-10 mm wide, upper surface nearly glabrous except for long hairs near base and margins, lower surface appressed-pubescent; panicle 5-9 cm long; spikelets 2.7-2.9 mm long. Autumnal phase spreading-decumbent, the stiff culms rather loosely branching from middle and upper nodes. Dry sandy woods, Cities of Norfolk and Virginia Beach, Russell and Arlington Counties. Harvill *et al.*, list *D. ovale* as a synonym of *D. acuminatum*. Gould and Clark do not.

Dichanthelium acuminatum (Swartz) Gould & Clark. Southern panic.

Basionym: *Panicum acuminatum* Swartz.

Synonyms: *Panicum albemarlense* Ashe; *Panicum auburne* Ashe; *Panicum huachucae* Ashe; *Panicum implicatum* Scribn.; *Panicum langinosum* Ell.; *Panicum longiligulatum* Nash; *Panicum meridionale* Ashe; *Panicum pseudopubescent* Nash; *Panicum spretum* Schult.; *Panicum tennesseense* Ashe; *Panicum villosissimum* Nash; *Panicum wrightianum* Scribn.

Plants with a well-developed rosette of broad, short basal leaves; culms 15-70 (-80) cm tall, usually becoming much-branched in age and commonly forming mats or pads of reduced branches and small few-flowered panicles, the nodes and internodes glabrous or more commonly hairy; ligule hairs well-developed, mostly 2-5 mm long but as short as 1 mm long; leaves glabrous to variously hairy; panicles

open or somewhat contracted, 2-12 cm long; spikelets ovate, elliptic or slightly obovate, glabrous or more commonly pubescent, 0.8-2.7 mm long; first glume broad, rounded or abruptly pointed, one-fifth to one-third as long as spikelet. Mostly in moist sandy soil of woodlands and woods borders scattered throughout the state.

Dichanthelium dichotomum (L.) Gould forking panic. Bushy panic.

Basionym: *Panicum dichotomum* L.

Synonyms: *Panicum annulum* Ashe; *Panicum barbutatum* Hitchc.; *Panicum caerulescens* Hack. ex Hitchc.; *Panicum clutei* Nash; *Panicum ensifolium* Baldw. ex Ell.; *Panicum lucidum* Ashe; *Panicum mattamuskeetense* Ashe; *Panicum microcarpon* Muhl. ex Ell.; *Panicum nitidum* Lam.; *Panicum roanokense* Ashe; *Panicum tenue* Muhl.; *Panicum trifolium* Nash; *Panicum yadkinense* Ashe.

Vernal phase often purplish; culms slender, erect from a knotted crown, 30-50 cm tall, lower nodes sometimes with a few spreading hairs; blades spreading, 4-8 mm wide, glabrous; panicle 4-9 cm long, the axis and branches flexuous; spikelets 2 mm long, elliptic, glabrous; second glume shorter than fruit at maturity. Autumnal phase much branched at middle nodes, lower part usually erect and devoid of blades, giving plants the appearance of miniature trees; blades numerous, often involute. Dry or sterile woods, swamps, or wet places.

Dichanthelium consanguineum (Kunth.) Gould & Clark. No common name known.

Basionym: *Panicum consanguineum* Kunth.

Vernal culms ascending or spreading, 20-50 cm tall, densely felty-villose, especially the lower; blades 7-11 cm long, 5-8 mm wide, villose or nearly glabrous above; panicle 4-8 cm long, 5-8 mm wide, villose or nearly glabrous above, the lower branches narrowly ascending; spikelets 2.6-2.8 mm long, obovate, papillose-villose. Autumnal phase spreading or decumbent, the numerous branches somewhat flabellately fascicled, the blades 3-4 cm long, 2-3 mm wide, flat, thin, papery. Sandy pine woods of Chesterfield, King George, Prince George and Southampton Counties.

Digitaria Heister. Crabgrass.

Annual or perennial; culms erect, creeping or decumbent, racemes slender, digitate or approximate on short axis; first glume minute or wanting, second glume equalling or shorter than sterile lemma; fertile lemma cartilaginous with hyaline margins.

1. Rachis winged or flat-margined, the margin as wide as the central rib; plants annual, creeping at least at base 2
 - 1'. Rachis wingless or with a very narrow margin, triangular; plants not creeping, annual or perennial 4
 2. Sheaths glabrous; fertile lemma brown *D. ischaemum*
 - 2'. Sheaths pilose or villose; fertile lemma pale 3
 3. Spikelets 1.5-1.7 mm long; pedicels terete, glabrous *D. serotina*
 - 3'. Spikelets 2.5-3.5 mm long; pedicels angled, scabrous *D. sanguinalis*
 4. Spikelets 2-2.5 mm long; culms 0.75-1.5 m tall *D. villosa*
 - 4'. Spikelets 1.5-1.7 mm long; culms 10-60 cm tall *D. filiformis*
- Digitaria ischaemum* (Schreb.) Schreb. ex Muhl. Smooth crabgrass.

Erect or usually soon decumbent-spreading, resembling *D. sanguinalis* but not so coarse or tall; foliage glabrous, bluish or purplish; racemes mostly 2 to 6, 4-10 cm long, the rachis with thin wings wider than the midrib; spikelets about 2 mm long; first glume hyaline, obscure; second glume and sterile lemma as long as the dark fertile lemma, pubescent with capitellate hairs. Waste places, often a troublesome weed in lawns scattered throughout the state. Introduced from Eurasia.

Digitaria serotina (Walt.) Michx. No common name known.

Creeping, sometimes forming extensive mats; flowering culms ascending or erect, 10-30 cm tall; leaves crowded on the creeping culms, the blades short; sheaths villose; blades 2-8 cm long, 3-7 mm wide; racemes usually 3 to 5, slender, often arcuate, 3-10 cm long, the rachis with thin wings wider than the midrib; spikelets pale, about 1.7 mm long; first glume wanting; second glume about one-third as long as the sterile lemma, both finely pubescent; fertile lemma pale. Pastures and waste places, Suffolk.

Digitaria sanguinalis (L.) Scop. Crabgrass. Large crabgrass. Hairy crabgrass. Common crabgrass.

Plant branching and spreading, often purplish, rooting at the decumbent base, the culms sometimes as much as 1 m long, the flowering shoots ascending; sheaths, at least the lower, papillose-pilose; blades 5-10 mm wide, pubescent to scaberulous; racemes few to several, 5-15 cm long, rarely longer, digitate, with usually 1 or 2 whorls a short distance below; spikelets about 3 mm long; first glume minute but evident; second glume about half as long as the spikelet, narrow; ciliate, sterile lemma strongly nerved, the lateral internerves appressed-pubescent, the hairs sometimes spreading at maturity; fertile lemma pale. Fields, gardens and waste places, a troublesome weed in lawns and cultivated ground throughout the state. Introduced from Europe.

Digitaria villosa (Walt.) Pers. No common name known.

Perennial at least in the southern states, in large tufts, purplish at base; culms 0.75-1.5 m tall, rarely branching; sheaths, at least the lower, grayish villose, sometimes sparsely so; blades elongate, 3-6 mm wide, often flexuous, from softly pilose to nearly glabrous; racemes 2 to 7, narrowly ascending, rarely somewhat spreading, rather distant, often naked at base, sometimes interrupted; spikelets 2-2.5 mm long, usually densely pubescent with softly capitellate hairs, the hairs longer than in *D. filiformis*, and sometimes only obscurely capitellate, the spikelets otherwise very like those of *D. filiformis*. Sandy fields and woods of Coastal Plain.

Digitaria filiformis (L.) Koel. Fingergrass.

Culms in small tufts, slender, usually erect, 10-60 cm tall, rarely taller, those of a tuft very unequal; lower sheaths pilose, the upper mostly glabrous; blades erect, usually 5-15 cm long (longer in more robust plants), 1-4 mm wide; racemes mostly 1 to 5, unequal, erect or ascending, mostly less than 10 cm long, somewhat distant, not fascicled; spikelets 1.5-1.7 mm long; first glume wanting; second glume and sterile lemma pubescent with short capitellate hairs, sometimes nearly glabrous, the glume shorter than the spikelet; fertile lemma dark brown, slightly apiculate. Sandy fields and sterile open ground scattered throughout the state.

Distichlis Raf. Saltgrass.

Low, dioecious perennials with extensively creeping scaly rhizomes, sometimes stolons, erect rather rigid culms and dense few-flowered panicles; spikelets several to many-flowered, the rachilla of the pistillate spikelets disarticulating above the glumes and between the florets; glumes unequal, broad, acute, keeled, 3- to 7-nerved, the lateral nerves sometimes faint; lemmas closely imbricate, firm, the pistillate coriaceous, acute or subacute, with 9 to 11 mostly faint nerves, palea as long as lemma or shorter.

Distichlis spicata (L.) Greene. Seashore saltgrass. Spikegrass.

Culms 10-40 cm tall, sometimes taller; leaves numerous, the sheaths closely overlapping, the spreading blades conspicuously distichous, flat to involute, sharp-pointed, mostly less than 10 cm long; panicle usually pale or greenish, 1-6 cm long, rarely longer; spikelets mostly 5- to 9-flowered, mostly 6-10 mm long, compressed; lemmas 3-6 mm long, the pistillate more coriaceous and more closely imbricate than the staminate; palea rather soft, narrow, the keels narrowly winged, entire; anthers about 2 mm long. Seashores, forming dense colonies in Coastal Plain.

Echinochloa Beauv.

Coarse, often succulent, annuals or perennials; panicle rather compact, of short, densely flowered, one-sided racemes along a main axis; spikelets planoconvex, often stiffly hispid, with one perfect flower; glumes unequal with stiff hairs; sterile lemma with an apical awn; fertile lemma and palea papery, long-pointed.

1. Racemes simple, rather distant, 1-2 cm long; spikelets crowded in about 4 rows, the awn of the sterile lemma reduced to a short point; blades 3-6 mm wide *E. colonum*
- 1'. Racemes more or less branched, usually more than 2 cm long; spikelets irregular, crowded and fascicled, usually not arranged in rows, awn of sterile lemma variable; blades usually more than 5 mm wide 2
2. Sheaths smooth; awns variable, but the panicle not a dense mass of long-awned spikelets *E. crusgalli*
- 2'. Sheaths, at least the lower, hispid or scabrous; panicle dense, the spikelets long-awned *E. walteri*

Echinochloa colonum (L.) Link. Jungle-rice. Jungle ricegrass. Shama millet.

Culms prostrate to erect, 20-40 cm long; blades rather lax, 3-6 mm wide, occasionally transversely zoned with purple; panicle 5-15 mm long; racemes several, 1-2 cm long, appressed or ascending, single or occasionally two approximate, the lower usually distant as much as 1 cm; spikelets about 3 mm long, crowded, nearly sessile; second glume and sterile lemma short-pointed, rather soft, faintly nerved, the nerves weakly hispid-scabrous. Ditches and moist places of Coastal Plain. Introduced.

Echinochloa crusgalli (L.) Beauv. Barnyard grass.

Culms erect to decumbent, stout, as much as 1 m or even 1.5 m tall, often branching at base; sheaths glabrous; blades elongate, 5-15 mm wide; panicle erect or nodding, purple-tinged, 10-20 cm long; racemes spreading, ascending or appressed, the lower somewhat distant, as much as 10 cm long, sometimes branched, the upper approximate; spikelets crowded, about 3 mm long, excluding the awns;

internerves hispidulous; nerves strongly tuberculate-hispid; awn variable, mostly 5-10 mm long on at least some of the spikelets, sometimes as much as 3 cm. Moist open places, ditches, cultivated fields and waste ground throughout the state.

Echinochloa walteri (Pursh) Hiller. No common name known.

Culms usually stout, erect, 1-2 m tall; sheaths papillose-hispid or papillose only, sometimes only the lower sheaths hispid or the hairs on the margins only; blades elongate; panicle dense, nodding, mostly 20-30 cm long, purplish; spikelets about 4 mm long, less turgid than in *E. crusgalli*; the stiff hairs on the nerves not tuberculate; awns mostly 1-2.5 cm long. Wet places, often in shallow water or brackish marshes of Coastal Plain and Piedmont; one report from Montgomery County.

Eleusine Gaertn.

Annuals with 2 to several rather stout spikes, digitate at summit of culms, sometimes with 1 or 2 a short distance below, or rarely with a single spike; spikelets few to several-flowered, compressed, sessile and closely imbricate in 2 rows along one side of a rather broad rachis, not prolonged beyond spikelets; rachilla disarticulating above glumes and between florets; glumes unequal, rather broad, acute, 1-nerved, shorter than first lemma; lemmas acute, with 3 strong green nerves close together forming a keel.

Eleusine indica (L.) Gaertn. Goosegrass. Yardgrass. Crabgrass. Wiregrass.

Branching at base, ascending to prostrate, very smooth; culms compressed, usually less than 50 cm long but sometimes as much as 1 m; blades flat or folded, 3-8 mm wide; spikes mostly 2 to 6, rarely more, or but 1 in depauperate plants, flat, 4-15 cm long. Waste places, fields and open ground throughout the state.

Elymus L. Wild-rye. Wild ryegrass.

Erect perennials in clumps; spikes densely flowered, terminal; spikelets 2- to 6-flowered, sessile, usually in pairs at alternate notches of zigzag rachis; glumes equal, stiff, narrow, sharp-pointed or awned, placed side-by-side in front of florets; lemmas convex, sharp-pointed or awned.

1. Glumes very narrow and bristle-like, not broadened
above the base, nerves obscure *E. villosus*
- 1'. Glumes broader near the base, lanceolate or
narrower, strongly 3-to several-nerved 2
2. Awns divergently curved when dry; base of glumes
not terete *E. canadensis*
- 2'. Awns straight, base of glumes terete 3
3. Glumes about 1 mm wide about the middle, the bases
not bowed out; palea much shorter than lemma *E. riparius*
- 3'. Glumes 1.5-2 mm wide about the middle, the bases
bowed out; palea as long as lemma *E. virginicus*

Elymus villosus Muhl. Hairy wild-rye.

Culms in small tufts, ascending, slender, 60-100 cm tall; sheaths glabrous to pilose; blades flat, lax, pubescent on upper surface, glabrous and glossy to scabrous beneath; spike drooping, dense, 6-12 cm long; glumes subsetaceous, spreading, distinctly nerved above the firm cylindric nerveless divergent or somewhat bowed-out base, hirsute, 12-20 mm long; lemmas nerved toward the tip, hispidulous to

hirsute, 7-9 mm long, about 1.2 mm across the back, the straight slender awn 1-3 cm long. Moist or dry woods and shaded slopes scattered throughout the state.

Elymus canadensis L. Canada wild-rye.

Green or often glaucous; culms erect, tufted, mostly 1-1.5 m tall; sheaths glabrous or rarely pubescent; blades flat, scabrous or sparsely hispid on the upper surfaces, mostly 1-2 cm wide; spike thick and bristly, nodding or drooping, often interrupted below, 10-25 cm long, sometimes glaucous; spikelets commonly in threes and fours, slightly spreading; glumes narrow, mostly 2- to 4-nerved, scabrous, sometimes hispid but less so than the lemmas, the bases somewhat indurate and divergent but scarcely bowed out, the awn about as long as the body; lemmas scabrous-hirsute to hirsute-pubescent, rarely glabrous, strongly nerved above, the awn divergently curved when dry, 2-3 cm long. River banks, open ground and sandy soil of Fairfax, Rockingham, Albemarle, Surry, Patrick, James City, Arlington, Giles, Wythe and Smyth Counties.

Elymus riparius Wiegand. No common name known.

Culms rather slender, erect, 1-1.5 m tall, sheaths glabrous; blades rather thin, flat, 5-15 mm wide, scabrous; spike somewhat nodding, 7-20 cm long; glumes narrow, about 1 mm wide at the middle, 2- to 4-nerved, somewhat indurate but scarcely bowed out at base; lemmas minutely hispidulous to glabrous, the awn straight, mostly 2-3 cm long. River banks and low ground scattered throughout the state.

Elymus virginicus L. Virginia wild-rye. Terrell grass. Wild rye.

Culms tufted, erect, 60-120 cm tall; sheaths glabrous; blades flat, scabrous, mostly 5-15 mm wide; spike usually erect, often partly included, 5-15 cm long; glumes strongly nerved, firm, indurate, yellowish, nerveless and bowed out at the base leaving a rounded sinus, broadened above (1.5-2 mm wide), scabrous, the apex somewhat curved, tapering into a straight awn, about as long as the body or shorter; lemmas glabrous and nerved above, tapering into a straight awn usually about 1 cm long. Moist ground, low woods and along streams throughout the state.

Eragrostis Beauv. Lovegrass.

Annuals or perennials of various habits; spikelets few- to many-flowered, florets usually closely imbricate; glumes somewhat unequal, shorter than first lemma, acute or acuminate; lemmas acute or acuminate, keeled or rounded on back, 3-nerved; palea about as long as lemma, keel sometimes ciliate.

1. Plants annual 2
- 1'. Plants perennial 9
2. Plants creeping, rooting at nodes forming mats *E. hypnoides*
- 2'. Plants often decumbent at base, but not creeping
and forming mats 3
3. Spikelets mostly less than 5-flowered 4
- 3'. Spikelets mostly more than 5-flowered 5
4. Panicles two-thirds the entire length of plant or more,
diffuse; culms erect, closely tufted *E. capillaris*
- 4'. Panicles less than half entire length of plant, open but
scarcely diffuse; culms spreading or decumbent at base . . . *E. frankii*
5. Plants with glandular depressions on panicle branches,
keel of lemmas or on margins of blades or keel of sheaths . . 6

- 5'. Plants not glandular on branches nor lemmas 7
6. Spikelets 2.5 mm wide; glands prominent on keel
of lemmas *E. cilianensis*
- 6'. Spikelets 1.5-2 mm wide, glandular depressions mostly
on panicle branches and leaves *E. poaeoides*
7. Spikelets about 1 mm wide, linear, slender *E. pilosa*
- 7'. Spikelets 1.5 mm wide or wider, ovate to linear 8
8. Spikelets linear at maturity, appressed along primary
panicle branches *E. pectinacea*
- 8'. Spikelets ovate to ovate-oblong, rarely linear, if linear
not appressed along primary panicle branches *E. multicaulis*
9. Nerves of lemma obscure; lemma rounded on back *E. hirsuta*
- 9'. Nerves of lemma evident, usually prominent;
lemmas keeled 10
10. Spikelets approximate in a somewhat condensed panicle *E. curvula*
- 10'. Spikelets in an open panicle 11
11. Panicle purple, the branches slender but rigid *E. spectabilis*
- 11'. Panicle green to leaden, branches capillary, fragile *E. refracta*
- Eragrostis hypnoides* (Lam.) B.S.P. Creeping lovegrass.

Annual, branching, creeping, and matlike; blades scabrous or pubescent on the upper surface; panicle elliptic, loosely few-flowered, 1-6 cm long, sometimes somewhat capitate; spikelets several- to many-flowered, linear, mostly 5-10 mm long, sometimes as much as 2 cm long in a dense cluster; flowers perfect; lemmas glabrous, acute, 1.5-2 mm long; palea about half as long as the lemma; grain 0.15 mm long; anthers about 0.2 mm long. Sandy river banks and wet ground, scattered throughout the state.

Eragrostis capillaris (L.) Nees. Lacegrass.

Annual; culms erect, 20-50 cm tall, much-branched at base, the branches erect; sheaths pilose, at least on the margin, long-pilose at the throat; blades flat, erect, pilose on upper surface near the base, 1-3 mm wide; panicle oblong or elliptic, open, diffuse, usually two-thirds the entire height of the plant, the branches and branchlets capillary; spikelets long-pedicelled, 2- to 4-flowered, 2-3 mm long; glumes acute, 1 mm long; lemmas acute, about 1.5 mm long, obscurely nerved, rounded on the back, minutely scabrous toward the tip; grain 0.5 mm long, somewhat roughened. Dry open ground, open woods and fields throughout the state.

Eragrostis frankii C. A. Meyer. Frank's lovegrass.

Resembling *E. capillaris*; culms usually lower, spreading to erect; sheaths glabrous except the pilose throat; blades glabrous; panicle less than half the entire height of the plant, open but not diffuse, mostly less than half as wide as long, the branches ascending, the shorter pedicels not much longer than the spikelets; spikelets 3- to 5-flowered, 2-3 mm long. Sandbars, riverbanks and moist open ground in the western part of the state although it occurs in Chesapeake.

Eragrostis cilianensis (All.) Lutati. (Includes *E. megastachya* Link and *E. major* Host). Stinkgrass.

Weedy annual with disagreeable odor when fresh; culms ascending or spreading, 10-50 cm tall, with a ring of glands below the nodes; foliage sparsely beset with glandular depressions, the sheaths pilose at the throat; blades flat, 2-7 mm wide;

panicle erect, dark gray-green to tawny, usually rather condensed, sometimes open, 5-20 cm long, the branches ascending; spikelets oblong, compressed, 10- to 40-flowered, 5-15 mm long, 2.5-3 mm wide; lemmas in side view ovate, acutish, about 2.5 mm long, 1 mm wide from keel to margin, the keel scabrous toward apex and beset with a few glands, the lateral nerves prominent; palea about two-thirds as long as the lemma, minutely ciliate on the keels; grain ovoid, plump, 0.7 mm long; anthers 0.5 mm long. Cultivated ground, fields and waste places throughout the state. Introduced from the Old World.

Eragrostis poaeoides Beauv. ex Roem. & Schult. (= *E. minor* Host). Low lovegrass. Little lovegrass.

Annual; resembling *E. cilianensis*, mostly more slender; panicles rather more open, the spikelets smaller, 1.5-2 mm wide, the lemmas about 2 mm long, the glands sometimes obscure; anthers about 0.2 mm long. Waste places scattered throughout the state. Introduced from Europe.

Eragrostis pilosa (L.) Beauv. India lovegrass.

Weedy annual; culms slender, erect or ascending from a decumbent base, 10-50 cm tall; blades flat, 1-3 mm wide; panicle delicate, open, becoming somewhat diffuse, 5-20 cm long, the branches capillary, flexuous, ascending or spreading, finally somewhat implicate, the lower fascicled, sparsely long-pilose in the axils, spikelets gray to nearly black, linear, scarcely compressed, 3- to 9-flowered, 3-5 mm long, about 1 mm wide, the pedicels spreading, mostly longer than the spikelets; glumes acute, the first a little less than, the second a little more than, 1 mm long; lemmas loosely imbricate, the rachilla more or less exposed, rounded on the back, acute, 1.2-1.5 mm long, 0.5 mm wide from keel to margin, the nerves obscure; grain 0.6 mm long. Moist open ground and waste places throughout the state. Introduced from Europe.

Eragrostis pectinacea (Michx.) Nees. Tufted lovegrass.

Resembling *E. pilosa*; panicles less delicate, the axils glabrous or obscurely pilose, the somewhat larger spikelets appressed along the branches and branchlets, often longer than the pedicels; spikelets at maturity mostly linear, 5-8 mm long; lemmas 1.5-1.6 mm long, the rachilla not or scarcely exposed, the nerves evident; grain 6.8 mm long. Fields, waste places, open ground, moist places scattered throughout the state. Hitchcock notes that the name *E. pectinacea* has been misapplied to *E. spectabilis*.

Eragrostis multicaulis Stud. No common name known.

Annual; rather soft and lax; culms branching at base, erect to decumbent-spreading, 5-20 cm tall, sometimes taller; blades flat, usually 5-10 cm long, 1-2 mm wide; panicle open, mostly 4-10 cm long, about half as wide, the branches ascending or spreading, naked below, the spikelets appressed or ascending along the upper part, axils glabrous; panicle branches spikelet-bearing nearly to base; spikelets mostly 4- to 8-flowered, mostly 3-4 mm long. Waste places in Coastal Plain. Introduced from Eurasia.

Eragrostis hirsuta (Michx.) Nees. No common name known.

Perennial; culms erect, tufted, 50-120 cm tall; sheaths hirsute to glabrous, pilose at the throat and especially along the collar at each side; blades flat, elongate, 5-10 mm wide, becoming more or less involute, tapering to a fine point, scabrous on the upper surface; panicle diffuse, more than half the entire height of the plant, pilose

in the axils, branching 4 or 5 times; spikelets on long flexuous pedicels, ovate to ovate-oblong, 2- to 6-flowered (rarely to 8-flowered), 3-4 mm long; glumes acuminate, 1.5 and 2 mm long; lemmas rather turgid, 2 mm long, acute, the nerves obscure; grain oblong, 1 mm long, minutely striate and pitted. Dry soil, fields and open woods in eastern part of state.

Eragrostis curvula (Schrud.) Nees. Weeping lovegrass.

Culms 60-120 cm tall, densely tufted, erect, simple or sometimes branching at the lower nodes; sheaths narrow, keeled, glabrous or sparsely hispid, the lower densely hairy toward the base; blades elongate, involute, attenuate to a fine point, arcuate, spreading, scabrous; panicles 20-30 cm long, the branches solitary or in pairs, ascending, naked at the base, at least the lower, densely pilose in the axils; spikelets 7- to 11-flowered, 8-10 mm long, gray-green; lemmas about 2.5 mm long, obtuse or subacute, the nerves prominent. Cultivated for ornament and for erosion control throughout the state on road cuts.

Eragrostis spectabilis (Pursh) Stud. Purple lovegrass. Ticklegrass.

Perennial, in dense tufts, rarely producing short or slender rhizomes; culms stiffly erect to spreading, 20-60 cm tall; sheaths glabrous or pilose, conspicuously hairy at the throats; blades flat or folded, rather firm, stiffly ascending, tapering to a fine point, glabrous or rarely pilose, mostly 3-8 mm wide; panicle at first included at base, two thirds the entire height of the culm, diffuse, bright purple, rarely pale, branching 3 or 4 times, the axis stiff, the branches stiffly spreading toward maturity, rarely pilose, strongly pilose in the axis, the lower shorter than the middle ones, finally reflexed, the whole panicle breaking away and tumbling before the wind; spikelets long-pedicel, short-pedicel toward the ends of the branches, oblong to linear, 6- to 12-flowered, 4-8 mm long; glumes acute, a little more than 1 mm long; lemmas acute, about 1.5 mm long, slightly scabrous toward the tip, the lateral nerves prominent toward the base; palea somewhat bowed out, exposing the rather prominently short-ciliate keels; grain oval, dark-brown, 0.6 mm long. Sandy soil scattered throughout the state.

Eragrostis refracta (Muhl.) Scribn. No common name known.

Perennial; culms tufted, stiffly erect or spreading, 40-80 cm tall; sheaths glabrous, pilose at the throat; blades flat, elongate, more or less pilose on the upper surface near the base, 2-4 mm wide; panicle diffuse, fragile, usually more than half the entire height of the plant, branching 3 or 4 times, the branches capillary, spreading, lower branches usually finally reflexed, long-pilose in the axils, mostly 8- to 15-flowered, 5-12 mm long, about 2 mm wide, pale or gray; spikelets short-pedicel, appressed and distant along the nearly simple panicle branches; the lemmas on the average shorter than 2 mm. Low sandy soil throughout the state.

Erianthus Michx. Plumegrass.

Perennial, reedlike; panicles dense, silky; spikelets alike, in pairs along a slender axis, one sessile, the other pedicellate, rachis disarticulating below spikelets; glumes coriaceous, equal, usually copiously covered with long silky spreading hairs; sterile lemma hyaline; fertile lemma hyaline with midnerve extending into a slender awn; palea small, hyaline.

1. Spikelets naked, or nearly so, at base *E. strictus*
- 1'. Spikelets with a conspicuous tuft of hairs at base 2
2. Awn flat, spirally coiled at base, upper portion bent and

- flexuous or loosely spiral 3
- 2'. Awn terete or flattened at base, not coiled, upper portion straight or slightly flexuous 4
3. Basal hairs nearly as long as the brownish spikelets; panicle not hairy; culms usually glabrous below panicle . . *E. contortus*
- 3'. Basal hairs about twice as long as the yellowish spikelets; panicle conspicuously woolly; culms villose below panicle . *E. alopecuroides*
4. Basal hairs copious, much longer than spikelet; panicle conspicuously woolly *E. giganteus*
- 4'. Basal hairs rather sparse, shorter than spikelet; panicle not woolly 5
5. Uppermost blade not reduced, reaching summit of panicle; rachis joint and pedicel terete, sparsely long-pilose *E. brevibarbis*
- 5'. Uppermost blade usually much reduced; rachis joint and pedicel somewhat angled, sparsely short-pilose *E. coarctatus*

Erianthus strictus Baldw. Narrow plumegrass.

Culms 1-2 m tall, relatively slender, glabrous; nodes hirsute with stiff erect deciduous hairs; foliage glabrous, the lower sheaths narrow, crowded, the blades mostly 8-12 mm wide; panicle 20-40 cm long, strict, the branches closely appressed; spikelets brown, about 8 mm long, scabrous, nearly naked to sparsely short-hairy at base; awn straight, about 15 mm long; rachis joint and pedicel scabrous. Marshes and wet places of Coastal Plain.

Erianthus contortus Baldw. ex Ell. Bent-awn plumegrass.

Culms 1-2 m tall, glabrous or sometimes sparsely appressed-pilose below the panicle; nodes glabrous or pubescent with erect deciduous hairs; sheaths sparsely pilose at summit or glabrous; blades 1-1.5 cm wide, scabrous; panicle 15-30 cm long, narrow, the branches ascending but not closely appressed; spikelets 6-8 mm long, brownish, basal hairs nearly or about as long as the spikelet, awn about 2 cm long, spirally coiled at base; rachis joints and pedicels villose. Moist sandy pinelands or open ground of Sussex County.

Erianthus alopecuroides (L.) Ell. Silver plumegrass.

Culms robust, 1.5-3 m tall, appressed-villose below panicle and usually on nodes; sheaths pilose at summit; blades 1.2-2 cm wide, scabrous, pilose on upper surface toward base; panicle 20-30 cm long, silvery to tawny or purplish; spikelets 5-6 mm long, pale, sparsely villose, shorter than the copious basal hairs; awn 1-1.6 cm long, flat loosely twisted; rachis joint and pedicel long-villose. Damp woods, open ground and borders of fields mostly in Piedmont and Blue Ridge.

Erianthus giganteus (Walt.) Muhl. Sugar cane. Plumegrass.

Culms 1-3 m tall, appressed-villose below the panicle, the nodes appressed-hispid, the hairs deciduous; sheaths and blades from nearly glabrous to shaggy appressed-villose, the blades 8-15 mm wide; panicle 10-40 cm long, oblong or ovoid, tawny to purplish; spikelets 5-7 mm long, sparsely long-villose on the upper part, shorter than the copious basal hairs; awn 2-2.5 cm long, terete, straight or subflexuous, 1.5-1.6 cm long; rachis joint and pedicel sparsely long-pilose. Dry hills of Spotsylvania and Sussex Counties. Rare.

Erianthus brevibarbus Michx. Brown plumegrass.

Culms stout, nearly 2 m tall, with 9-10 nodes, glabrous; sheaths glabrous or sparingly pubescent at the summit; blades scabrous on upper surface, pilose at the base, 1-1.5 cm wide, the upper not reduced; panicle 35 cm long, tawny brown, not conspicuously woolly; spikelets 6-7 mm long; glumes acuminate, glabrous or with a few long hairs on the inflexed margins, the spreading basal hairs about two-thirds as long as the spikelet; awn terete, straight or subflexuous, 1.5-1.6 cm long. Moist places, Spotsylvania and Sussex Counties.

Erianthus coarctatus Fern. No common name known.

Culms relatively slender, 75-150 cm tall, subcompressed, the nodes bearded, appressed-pubescent, or glabrescent; sheaths glabrous, the lower narrow, somewhat keeled; blades 3-10 mm wide, scaberulous, the upper reduced; panicle 10-27 cm long, 2.5-4 cm wide, purplish-brown, not conspicuously woolly; spikelets 7-8 mm long; glumes acuminate, scaberulous, the first sometimes with a few long hairs on the back, the second without hairs on the inflexed margins, the basal hairs about half as long as the spikelet; awn terete, straight, 1.5-2.3 cm long, straight; rachis joint and pedicel somewhat angled, very sparsely short-pilose. Peaty, sandy, moist meadows, swales and swamp margins of Fall Belt. Rare.

Eriochloa H.B.K. Cupgrass.

Annual or perennial; often branching grasses with terminal panicles of several to many spreading or appressed racemes usually approximate along a common axis; spikelets more or less pubescent, solitary or sometimes in pairs, short-pedicel or sessile, in two rows on one side of a narrow rachis, the back of the fertile lemma turned from the rachis; lower rachilla joint thickened, forming a more or less ringlike, usually dark-colored callus below the second glume, the first glume reduced to a minute sheath about this and adnate to it; second glume and sterile lemma about equal, the lemma enclosing a hyaline palea or sometimes a staminate flower; fertile lemma indurate, minutely papillose-rugose, mucronate or awned, the awn often readily deciduous, margins slightly inrolled.

Eriochloa contracta Hitchc. Prairie cupgrass.

Annual; culms erect or sometimes decumbent at base, pubescent at least about the nodes, 30-70 cm tall; blades pubescent, usually not more than 5 mm wide; panicle usually less than 15 cm long, contracted, cylindric, the racemes appressed, closely overlapping, 1-2 cm long, the axis and rachises villose; spikelets 3.5-4 mm long, excluding the awn-tip, appressed villose; glume awn-tipped; sterile lemma slightly shorter, acuminate, empty; fruit 2-2.5 mm long, with an awn nearly 1 mm long. Open ground, ditches, low fields and wet places, Arlington County. Introduced.

Festuca L. Fescue.

Low or rather tall annuals or perennials; culms mostly tufted, erect; panicles terminal with 2- to several-flowered spikelets; glumes narrow, acute, unequal; lemmas narrow, sharp-pointed or tapering into a straight awn.

- | | |
|--|---------------------|
| 1. Plants annual | 2 |
| 1'. Plants perennial | 5 |
| 2. Spikelets mostly more than 5-flowered; lemma margin
inrolled, not scarious | <i>F. octoflora</i> |
| 2'. Spikelets mostly less than 5-flowered; lemmas usually
scarious-margined | 3 |

3. Lemmas appressed-pubescent over the back *F. sciurea*
- 3'. Lemmas glabrous, scabrous or ciliate, not pubescent
over the back 4
4. First glume two-thirds to three-fourths as long as
the second *F. dertonensis*
- 4'. First glume much shorter than second, 1-2 mm long *F. myuros*
5. Blades flat, rather soft and lax, mostly more than
3 mm wide 6
- 5'. Blades involute or if flat less than 3 mm wide 7
6. Spikelets oblong to linear, mostly 8- to 10-flowered and
more than 1 cm long *F. elatior*
- 6'. Spikelets ovate or oval, mostly not more than 5-flowered,
less than 1 cm long 8
7. Spikelets loosely scattered in a very open panicle with
long slender branches *F. obtusa*
- 7'. Spikelets somewhat aggregate toward the ends of rather
short branches of a less open panicle *F. paradoxa*
8. Culms decumbent at usually red, fibrillose base,
in loose tufts *F. rubra*
- 8'. Culms erect 9
9. Lemmas awnless *F. capillata*
- 9'. Lemmas awned *F. ovina*

Festuca octoflora Walt. Six-weeks fescue.

Culms erect, usually 15-30 cm tall, sometimes as much as 60 cm; blades narrow, involute, 2-10 cm long; panicle narrow, the branches short, appressed or spreading; spikelets 6-8 mm long, densely 5- to 13-flowered; glumes subulate-lanceolate, the first 1-nerved, the second 3-nerved, 3-4.5 mm long; lemmas firm, convex, lanceolate, glabrous or scabrous, 4-5 mm long, the margins not scarious; awn commonly 3-5, sometimes 7 mm long. Open sterile ground scattered throughout the state.

Festuca sciurea Nutt. No common name known.

Culms erect, 15-50 cm tall; blades less than 1 mm wide, often capillary, soft, mostly involute, 1-10 cm long; panicle narrow, 5-20 cm long; spikelets 4- to 6-flowered, 4-5 mm long; first glume 2 mm long, the second 3.5 mm long; lemmas 3-3.5 mm long, sparsely appressed-pubescent; awn 6-11 mm long. Open ground of Coastal Plain.

Festuca dertonensis (All.) Aschers. & Graebn. No common name known.

Culms to 60 cm tall, sheaths and narrow blades glabrous; panicle narrow, less than 20 cm long; first glume about 4 mm long, second 6-7 mm long; lemma lanceolate, scabrous on back toward apex, 7-8 mm long, awn 10-13 mm long. Dry hills and meadows, Accomack County. Rare in eastern United States.

Festuca myuros L. Rattail fescue.

Plants annual; culms erect; blades narrow, involute; spikelets mostly less than 5-flowered; panicle narrow, branches appressed; first glume 1-1.5 mm, the second 4-4.5 mm long; lemmas not ciliate. Open ground of Coastal Plain and Pulaski County. Introduced from Europe.

Festuca elatior L. English bluegrass. Meadow fescue. Tall meadow fescue.

Culms 50-120 cm tall; blades flat, 4-8 mm wide, scabrous above; panicle erect, or nodding at summit, 10-20 cm long, contracted after flowering, much branched or nearly simple, the branches spikelet-bearing nearly to base; spikelets usually 6- to 8-flowered, 8-12 mm long; glumes 3 and 4 mm long, lanceolate; lemmas oblong-lanceolate, coriaceous, 5-7 mm long, the scarious apex acutish, rarely short-awned. Meadows, roadsides and waste places scattered throughout the state. Native to Eurasia. This taxon includes *F. arundinacea* Schreb., Reed fescue, Alta fescue, and *F. pratensis* Huds., Meadow fescue.

Festuca obtusa Biehler. Nodding fescue.

Culms solitary or few in a tuft, mostly 50-100 cm tall; blades flat, lax, somewhat glossy, 4-7 mm wide; panicle nodding, very loose and open, the branches spreading, spikelet-bearing toward the ends, the lower usually reflexed at maturity; spikelets 3- to 5-flowered; glumes about 3 and 4 mm long; lemmas coriaceous, rather turgid, about 4 mm long, obtuse or acutish, the nerves very obscure. Low or rocky woods throughout the state.

Festuca paradoxa Desv. No common name known.

Culms few to several in a tuft, 50-110 cm tall, widely leaning; blades flat or subinvolute in drying, lax, 4-8 mm wide; panicle 12-20 cm long, heavily drooping, the slender scabrous branches not so long as in *F. obtusa*; the brownish spikelets somewhat aggregate toward the ends; spikelets 3- to 6-flowered; the lemmas more blunt. Low open ground and thickets of western Coastal Plain and Piedmont.

Festuca rubra L. Red Fescue.

Culms usually loosely tufted, bent or decumbent at the reddish or purplish base, occasionally closely tufted, erect to ascending, 40-100 cm tall; lower sheaths brown, thin, and fibrillose; blades smooth, soft, usually folded or involute; panicle 3-20 cm long, usually contracted and narrow, the branches mostly erect or ascending; spikelets 4- to 6-flowered, pale green or glaucous, often purple-tinged; lemmas 5-7 mm long, smooth, or scabrous toward apex, bearing an awn about half as long. Meadows, hills, bogs and marshes scattered throughout the state.

Festuca capillata Lam. (= *F. tenuifolia* Sibth.). Hair fescue. Slender fescue.

Densely tufted, more slender and lower than *F. ovina*; blades capillary, flexuous, usually more than half as long as the culm; spikelets smaller; lemmas about 3 mm long, awnless. Lawns and waste places, Fairfax, Giles and Montgomery Counties. Introduced from Europe.

Festuca ovina L. Sheep fescue.

Culms densely tufted, usually 20-40 cm tall; blades slender, involute, from very scabrous to glabrous, the innovations numerous in a basal cluster, 5-10 cm long or sometimes longer; panicle narrow, sometimes almost spikelike, 5-8 cm long, sometimes longer; spikelets mostly 4- to 5-flowered; lemmas about 4-5 mm long, short-awned. Open woods and stony slopes scattered throughout central and western parts of the state.

Glyceria R. Br. Mannagrass.

Tall aquatic or marsh perennials with unbranched culms; panicles terminal; spikelets several-flowered; glumes unequal, shorter than the florets; lemmas convex, firm with colorless margins.

1. Spikelets linear, nearly terete, usually 1 cm or more long,
appressed; panicles narrow, erect 2

- 1'. Spikelets ovate or oblong, more or less compressed,
usually not more than 5 mm long; panicles usually nodding 4
2. Lemmas acute, much exceeded by palea *G. acutiflora*
- 2'. Lemmas obtuse; palea about as long as, or slightly
longer than, lemma 3
3. Lemmas about 3 mm long *G. arkansana*
- 3'. Lemmas 4 to 7 mm long *G. septentrionalis*
4. Lemmas with 7 usually prominent nerves; second
glume 1-nerved; sheaths, at least the upper, closed from
below the summit 5
- 4'. Lemmas with 5 prominent nerves; second glume 3-nerved;
sheaths open *G. pallida*
5. Panicle contracted, narrow 6
- 5'. Panicle open, lax 7
6. Lemmas 3-4 mm long; panicle oblong, dense, usually not
more than 100 cm long *G. obtusa*
- 6'. Lemmas 2-2.5 mm long; panicle rather loose, nodding,
15-25 cm long *G. melicaria*
7. Nerves of lemma evident but not prominent *G. canadensis*
- 7'. Nerves of lemma prominent 8
8. First glume not more than 1 mm long *G. striata*
- 8'. First glume more than 1 mm long, usually about
1.5 mm long *G. grandis*

Glyceria acutiflora Torr. No common name known.

Culms compressed, lax, creeping and rooting below, 50-100 cm long; blades flat, lax, 10-15 cm long, 3-6 mm wide, scabrous on the upper surface; panicle 15-35 cm long, often partly included, the branches rather stiff, bearing 1 or 2 spikelets, or the lower 3 or more; spikelets 5- to 12-flowered, 2-4 cm long, 1-2 mm wide, the lateral pedicels 1-3 mm long; glumes about 2 and 5 mm long; lemmas 7-nerved, acute, scabrous, 6-8 mm long, exceeded by the acuminate, 2-toothed paleas. Wet soil and shallow water in northern ridges and valleys.

Glyceria arkansana Fern. No common name known.

Resembling *G. septentrionalis*; first glume 2-2.5 mm long; lemmas 3-3.5 mm long, hirtellous rather than scaberulous. Wet ground of Coastal Plain.

Glyceria septentrionalis Hitchc. Eastern mannagrass.

Culms 1-1.5 m tall, somewhat succulent; sheaths smooth; blades flat, mostly 10-20 cm long, 4-8 mm wide, usually smooth beneath, slightly scaberulous on the upper surface and margin; panicle 20-40 cm long, somewhat open, the branches as much as 10 cm long, several-flowered, often spreading at anthesis; spikelets 1-2 cm long, 6- to 12-flowered, the florets rather loosely imbricate; glumes 2-3 and 3-4 mm long; lemmas pale or green, about 4 mm long, narrowed only slightly at the summit, scaberulous, the paleas usually exceeding them. Shallow water and wet places, scattered throughout the state.

Glyceria pallida (Torr.) Trin. Pale mannagrass.

Culms slender, lax, ascending from a decumbent rooting base, 30-100 cm long; sheaths open, blades mostly 4-8 mm wide; panicle pale green, open, 5-15 cm long, the branches ascending, flexuous, finally more or less spreading; spikelets some-

what elliptic, 4- to 7-flowered, 6-7 mm long; glumes 1.5-2 and 2-2.5 mm long, the second 3-nerved; lemmas 2.5-3 mm long, scaberulous, obtuse, the scarious tip erose; anthers linear, about 1 mm long; caryopsis with a crown of white hairs 0.2-0.25 mm long. Shallow cold water of Coastal Plain, also Highland Co. (Transferred to *Puccinellia* by Clausen, 1952).

Glyceria obtusa (Muhl.) Trin. No common name known.

Culms erect, often decumbent at base, 50-100 cm tall, rather firm; blades elongate, erect, mostly smooth, flat or folded, 2-6 mm wide; panicle erect, oblong or narrowly elliptic, dense, 5-15 cm long, the branches ascending or appressed; spikelets mostly 4- to 7-flowered, 4-6 mm long, green or tawny, the rachilla joints very short; glumes broad, scarious, 1.5 and 2 mm long; lemmas firm, faintly nerved, smooth, 3-4 mm long, obtuse, the scarious tip narrow, often revolute. Bogs and marshy places mostly near the coast; also Warren, Rappahannock and Augusta Counties.

Glyceria melicaria (Michx.) Hubb. No common name known.

Culms slender, solitary or few, 60-100 cm tall; blades elongate, scaberulous, 2-5 mm wide; panicle narrow but rather loose, nodding, 15-25 cm long, the branches erect, rather distant; spikelets 3- or 4-flowered, about 4 mm long, green; glumes about 1.5 and 2 mm long, acutish, smooth, the nerves rather faint. Swamps and wet woods of valleys and ridges in western part of the state.

Glyceria canadensis (Michx.) Trin. Rattlesnake mannagrass. Rattlesnake grass.

Culms erect, solitary or few in a tuft, 60-150 cm tall; blades scabrous, 3-7 mm wide; panicle open, 15-20 cm long, nearly as wide, the branches rather distant, drooping, naked below; spikelets ovate or oblong, 5- to 10-flowered, 5-6 mm long, the florets crowded, spreading; glumes about 2 and 3 mm long; lemmas 3-4 mm long, the nerves obscured in the firm tissue of the lemma; palea bowed out on the keels, the floret somewhat tumid. Bogs and wet places in Alleghany, Augusta, Giles, Highland, Montgomery and Prince George Counties.

Glyceria striata (Lam.) Hitchc. Fowl mannagrass. Fowl meadowgrass.

Plants in large tussocks, pale green; culms erect, slender, rather firm, 30-100 cm tall, sometimes taller; blades erect or ascending, flat or folded, moderately firm, usually 2-6 mm wide, sometimes to 9 mm; panicle ovoid, open, 10-20 cm long, nodding, the branches ascending at base, drooping, naked below; spikelets ovate or oblong, 3- to 7-flowered, 3-4 mm long, often purplish, somewhat crowded toward the ends of the branchlets; glumes about 0.5 and 1 mm long, ovate, obtuse; lemmas oblong, prominently 7-nerved, about 2 mm long, the scarious tip inconspicuous; palea rather firm, about as long as the lemma, the smooth keels prominent, bowed out. Moist meadows and wet places throughout the state.

Glyceria grandis A. Wats. American mannagrass. Reed meadowgrass.

Culms tufted, stout, 1-1.5 m tall; blades flat, 6-12 mm wide; panicle large, very compound, 20-40 cm long, open, nodding at summit; spikelets 4- to 7-flowered, 5-6 mm long; glumes whitish, about 1.5 and 2 mm long; lemmas purplish, about 2.5 mm long; palea rather thin, about as long as the lemma. Banks of streams, marshes and wet places, Arlington, Highland, James City and New Kent Counties.

Gymnopogon Beauv.

Perennials with short, stiff, flat blades, often folded in drying, spikes numerous, long, slender, divergent or reflexed; spikelets 1- or rarely 2- or 3-flowered, nearly sessile, appressed, and usually remote in 2 rows along one side of a slender continuous rachis; glumes narrow, acuminate, 1-nerved, usually longer than floret; lemmas narrow, 3-nerved, the lateral nerves near the margin, apex minutely bifid, bearing a slender awn between the teeth.

1. Awn 4-6 mm long, longer than lemma *G. ambiguus*
 - 1'. Awn 1-3 mm long, usually shorter than lemma *G. brevifolius*
- Gymnopogon ambiguus* (Michx.) B.S.P. No common name known.

Culms 30-60 cm tall in small clumps with short scaly rhizomes, suberect to spreading, rigid, sparingly branching; leaves numerous, approximate with overlapping sheaths, or the lower rather distant; blades spreading, 5-15 mm mostly about 10 mm wide, the base rounded-truncate; spikes 10-20 cm long, floriferous from base, the lower spikelets often remote; glumes 4-6 mm long; lemma with an awn 4-6 mm long, the rudiment bearing a delicate shorter awn. Dry pinelands of Coastal Plains.

Gymnopogon brevifolius Trin. No common name known.

Differing from *G. ambiguus* in the longer, more slender, somewhat straggling culms, narrower, less crowded blades, and in the subcapillary spikes, floriferous only on the upper half or third; lemma awnless or with a minute awn. Dry ground of Coastal Plain.

Holcus L.

Perennials with flat blades and contracted panicles; spikelet 2-flowered, the pedicel disarticulating below the glumes, the rachilla curved and somewhat elongate below first floret, not prolonged above second floret; glumes about equal, longer than the 2 florets; first floret perfect, lemma awnless, second floret staminate, lemma with short awn on back.

Holcus lanatus L. Velvet grass. Yorkshire fog.

Plant grayish, velvety-pubescent; culms erect, 30-100 cm tall, rarely taller; blades 4-8 mm wide; panicles 8-15 cm long, contracted, pale, purple-tinged; spikelets 4 mm long; glumes villose, hirsute on the nerves, the second broader than the first, 3-nerved; lemmas smooth and shining, the awn of the second hooklike. Open ground, meadows and moist places throughout the state.

Hordeum L. Barley

Annual or perennial low or rather tall grasses with flat blades; spikes dense, bristly; spikelets 1-flowered, 3 together at each node of the articulate rachis; middle spikelet sessile, lateral ones pediceled; glumes narrow, often subulate and awned, standing in front of spikelet; lemmas rounded on back, back turned from rachis, 5-nerved, usually obscurely so, tapering into a long awn.

1. Plants perennial; awns slender; auricle wanting *H. jubatum*
- 1'. Plants annual, branching at base; awns mostly stouter 2
2. Blades with prominent auricle at base *H. murinum*
- 2'. Blades without auricles *H. pusillum*

Hordeum jubatum L. Foxtail barley. Squirreltail grass.

Perennial, tufted; culms erect, or decumbent at base, 30-60 cm tall; blades 2-5 mm wide, scabrous; spike nodding, 5-10 cm long, about as wide, soft, pale; lateral

spikelets reduced to 1 to 3 spreading awns; glumes of perfect spikelet awnlike, 2.5 - 6 cm long, spreading; lemma 6-8 mm long with an awn as long as the glumes. Open ground, meadows and waste places. Sparse in western part of state.

Hordeum murinum L. Wild barley. Foxtail. Wall barley.

Annual, without a distinctly bulbous swelling at the base of the culm; leaves broad, flat, with long distinct auricles; spikes long and comparatively broad, central spikelets less than 2 mm wide, with awns of lemmas very long and stiff, glumes flattened, more or less lanceolate, often ciliate in basal parts; lateral spikelets large, inflated, central floret self-pollinating, usually closed, lateral, usually male flowers often open; caryopsis more than 3 mm broad. Riverbeds, waterholes, or marsh areas, James City, Chesterfield and Fluvanna Counties. Native of northeast Europe, North Africa, mideast to central Asia. *Hordeum murinum* ssp. *glaucum* (Steudel) Tzvelez is common in the summer annual habitats of western USA, while *Hordeum murinum* ssp. *leporinum* (Link) Arcang. is often found in winter annual habitats. The *H. murinum* of Harvill is probably ssp. *leporinum* (Bothmer and Jacobsen, 1985). Hitchcock and Chase (1951) noted that *H. leporinum* Link, and *H. stebbensii* Coon have been confused with *H. murinum* of Europe.

Hordeum pusillum Nutt. Little barley. Little wild barley.

Annual; culms 10-35 cm tall; blades erect, flat, the auricle wanting; spike erect, 2-7 cm long, 10-14 mm wide; first glume of the lateral spikelets and both glumes of the fertile spikelet dilated above the base, attenuate into a slender awn 8-15 mm long, the glumes very scabrous; lemma of central spikelet awned, of lateral spikelets awn-pointed. Plains and open, especially alkaline, ground throughout eastern and central part of the state.

Hystrix Moench.

Erect perennials with flat blades and bristly, loose-flowered spikes; spikelets 2- to 4-flowered, 1 to 4 at each node of a continuous flattened rachis, horizontally spreading or ascending at maturity; glumes reduced to short or minute awns, the first usually obsolete, both often wanting in the upper spikelets; lemmas convex, rigid, tapering into long awns, 5-nerved, the nerves obscure except toward the tip; palea about as long as body of lemma.

Hystrix patula Moench. Bottlebrush. Bottlebrush grass.

Culms slender, 60-120 cm tall; sheaths glabrous or scabrous, rarely retrorsely pubescent, blades mostly 7-15 mm wide; spike nodding, 8-15 cm long, the internodes of the slender rachis 5-10 mm long; spikelets mostly in pairs, 1-1.5 cm long, horizontally spreading toward maturity; lemmas glabrous or sometimes coarsely pubescent, the awns 1-4 cm long, slender, straight. Moist or rocky woods throughout the state.

Leersia Swartz. Ricegrass.

Perennials; spikelets 1-flowered, in short racemes arranged in open panicles; glumes none; lemma boat-shaped, awnless; palea as long as lemma.

- 1. Spikelets broadly oval, 3-4 mm wide *L. lenticularis*
- 1'. Spikelets elliptic, not more than 2 mm wide 2
- 2. Panicle narrow, the branches ascending or appressed . . . *L. hexandra*
- 2'. Panicle open, the capillary branches finally spreading . . . 3
- 3. Lower panicle branches solitary; spikelets 3 mm long,
1 mm wide *L. virginica*

- 3'. Lower panicle branches fascicled; spikelets 5 mm long,
1.5-2 mm wide *L. oryzoides*
Leersia lenticularis Michx. Catchfly grass.

Culms straggling, 1-1.5 m tall, with creeping scaly rhizomes; sheaths scabrous at least toward the summit; blades lax, 1-2 cm wide; panicle open, drooping, 10-20 cm long, the branches ascending or spreading, naked below, branched above, branchlets bearing closely imbricate spikelets along one side; spikelets pale, broadly oval, very flat, 4-5 mm long, sparsely hispidulous, the keels bristly ciliate. Ditches and swamps of Coastal Plain.

Leersia hexandra Swartz. Southern cutgrass.

Culms slender, weak, usually long-decumbent from a creeping and rooting base, with slender rhizomes and extensively creeping leafy stolons, the flowering culms upright; blades rather stiff, 2-5 mm wide; panicle narrow, 5-10 cm long, the branches ascending or appressed, floriferous nearly to the base; spikelets oblong, about 4-5 mm long, a little more than 1 mm wide, often purplish, sparsely hispidulous, the keel bristly ciliate. Shallow water, ditches and wet places near the coast, Arlington and Sussex Counties.

Leersia virginica Willd. Whitegrass.

Culms slender, weak, branching, 50-120 cm tall, with clusters of very scaly rhizomes much stouter than the culm base; blades relatively short, 6-12 mm wide; panicle open, 10-20 cm long, the capillary branches rather distant, stiffly spreading, naked below, those of the branches smaller, sometimes included in the sheath; spikelets oblong, closely appressed to the branchlets, about 3 mm long and 1 mm wide, sparsely hispidulous, the keels short-hispid. Low woods and moist places throughout the state.

Leersia oryzoides (L.) Swartz. Rice cutgrass.

Culms slender, weak, often decumbent at base, 1-1.5 m tall, with slender creeping rhizomes; sheaths and blades strongly retrorsely scabrous, the blades mostly 8-10 mm wide; panicles terminal and axillary, 10-20 cm long, the flexuous branches finally spreading, the spikelets more loosely imbricate than in *L. lenticularis*; spikelets elliptic, 5 mm long, 1.5-2 mm wide, sparsely hispidulous, the keels bristly ciliate, axillary panicles partly included in the sheaths, the spikelets cleistogamous. Marshes, river banks and wet places, often forming a zone around ponds and lakes throughout the state.

Leptochloa Beauv. Sprangle top.

Annuals; panicles long or short; spikes or racemes usually slender, numerous, one common axis; spikelets 2- to several-flowered, sessile or short-pedicelled; glumes unequal or nearly equal, usually shorter than first lemma; lemmas obtuse or acute, sometimes 2-toothed and mucronate or short-awned from between the teeth.

1. Sheaths papillose; spikelets mostly 1-2 mm long *L. filiformis*

- 1'. Sheaths smooth or scabrous, not papillose; spikelets
more than 2 mm long *L. fascicularis*

Leptochloa filiformis (Lam.) Beauv. Red sprangle top.

Annual; the foliage and panicles often reddish or purple; culms erect or branching and geniculate below, 40-70 cm tall, or often dwarf; sheaths papillose-pilose, sometimes sparsely so; blades flat, thin, as much as 1 cm wide; panicle

somewhat viscid, of numerous approximate slender racemes, 5-15 cm long, on an axis mostly about half the entire length of the culm; spikelets 3- to 4-flowered, 1-2 mm long, rather distant on the rachis; glumes acuminate, longer than the first floret, often as long as the spikelet; lemmas awnless, pubescent on the nerves, 1.5 mm long. Open or shady ground, a common weed in gardens and fields of Coastal Plain.

Leptochloa fascicularis (Lam.) A. Gray. No common name known.

Annual, somewhat succulent; culms erect to spreading or prostrate, freely branching, 30-100 cm tall; blades flat to loosely involute; panicles more or less included, mostly 10-20 cm long, often smaller, occasionally longer, the racemes several to numerous, as much as 10 cm long, usually ascending or appressed, or at maturity spreading; spikelets usually overlapping, 7-12 mm long, 6- to 12 flowered; lemmas 4-5 mm long, the lateral nerves pubescent below, acuminate, the awn from short to as long as the body. Brackish marshes along coast.

Leptoloma Chase.

Branching perennials with brittle culms, felty-pubescent at base, flat blades, and open or diffuse panicles, these breaking away at maturity, becoming tumbleweeds; spikelets on slender pedicels; first glume minute or obsolete; second glume 3- to 5-nerved, nearly as long as the 5- to 7-nerved sterile lemmas, a more or less prominent strip of appressed silky hairs down the internerves and margins of each, the sterile lemma empty or enclosing a minute nerveless rudimentary palea; fertile lemma cartilaginous, elliptic, acute, brown, the delicate hyaline margins enclosing the palea.

Leptoloma cognatum (Schult.) Chase. Fall witchgrass.

Ascending from a decumbent, knotty, often densely hairy base, often forming large bunches, pale green, leafy; culms 30-70 cm long; blades mostly less than 10 cm long, 2-6 mm wide, rather rigid; panicle one-third to half the entire height of the plant, purplish and short-exserted at maturity, very diffuse, the capillary branches soon widely spreading, pilose in the axils; the spikelets solitary on long capillary pedicels, narrowly elliptic, 2.5-3 mm long, abruptly acuminate. Dry soil and sandy fields. Coastal Plain and Fall Belt.

Lolium L. Ryegrass.

Annuals or perennials; culms erect, unbranched; spikes terminal, usually flat; spikelets several-flowered, single in alternate notches of zig-zag rachis; first glume wanting, second outward, equalling or exceeding second floret; lemmas rounded on back, obtuse, acute or awned.

1. Glume shorter than spikelet 2
- 1'. Glume as long or longer than spikelet *L. temulentum*
2. Lemmas nearly or quite awnless; culms subcompressed . . . *L. perenne*
- 2'. Lemmas at least the upper, awned; culms cylindric *L. multiflorum*

Lolium temulentum L. Darnel.

Annual; culms 60-90 cm tall; blades mostly 3-6 mm wide; spike strict, 15-25 cm long, glume about 2.5 cm long, as long as or longer than the 5- to 7-flowered spikelet, firm, pointed; florets plump; the lemmas as much as 8 mm long, obtuse, awned, the awn 6-12 mm long. Grainfields and waste places, Coastal Plain and Piedmont.

Lolium perenne L. Perennial ryegrass. Common darnel. English ryegrass.

Shortlived perennial; culms erect or decumbent at the commonly reddish base, 30-60 cm tall; auricles at summit of sheath, minute or obsolete; foliage glossy, the

blades 2-4 mm wide; spike often subfalcate, mostly 15-25 cm long; spikelets mostly 6- to 10-flowered; lemmas 5-7 mm long, awnless or nearly so. Meadows and waste places scattered throughout the state. Introduced from Europe.

Lolium multiflorum Lam. Italian ryegrass. Annual ryegrass.

Differing from *L. perenne* in the more robust habit, to 1 m tall, pale or yellowish at base, auricles at summit of sheaths prominent; spikelets 10- to 20-flowered, 1.5-2.5 cm long; lemmas 7-8 mm long, at least the upper awned. Meadows and waste places throughout the state. Introduced from Europe. Harvill *et al.* regard *L. multiflorum* as a synonym of *L. perenne*.

Manisuris L.

Perennial, slender, moderately tall, or tall grasses with usually numerous glabrous cylindric or flattened solitary racemes; spikelets awnless, in pairs at the nodes of a thickened articulate rachis, one sessile and perfect, the other pedicellate, rudimentary, the pedicel thickened and appressed to the rachis, the sessile spikelet fitting closely against the rachis, forming a cylindric or flattened raceme; glumes mostly obtuse, the first coriaceous, fitting over the hollow containing the spikelet, the keels winged at the summit, the second less coriaceous than the first; sterile lemma, fertile lemma and palea thin and hyaline. *Manisuris* is considered to be *Coelorachis* in Gould and Shaw (1983).

Manisuris rugosa (Nutt.) Kuntze. No common name known.

Culms mostly rather stout, 70-120 cm tall, freely branching; sheaths compressed-keeled; blades commonly folded, 3-8 mm wide; flowering branches often numerous, the racemes 4-8 cm long, partly included in brownish sheaths; rachis joint and pedicel contracted in the middle; sessile spikelet 3.5-5 mm long, the first glume strongly and irregularly transversely ridged, the keels narrowly winged toward the summit. Moist to wet pine woods, Sussex County.

Melica L. Melic grass.

Rather tall perennials; base of culm often swollen into a corm; sheaths closed, blades flat; panicles narrow; spikelets relatively large, 2- to several-flowered; glumes somewhat unequal, thin, papery, scarious-margined; lemmas convex, scarious-margined, callus not bearded.

1. Glumes nearly as long as the 2-flowered spikelets *M. mutica*

1'. Glumes shorter than the 3- to 5-flowered spikelets *M. nitens*

Melica mutica Walt. Two-flower melic grass.

Culms 60-100 cm tall, erect, loosely tufted; sheaths scabrous or somewhat pubescent; blades flat, 2-5 mm wide; panicle 10-20 cm long, nearly simple, with 1 to few short, spreading, few-flowered branches below; spikelets broad, pale, 7-10 mm long, usually 2-flowered, the florets spreading, pendulous on slender pedicels, pubescent at the summit, the spikelets entire; glumes nearly as long as the spikelet; lemmas scaberulous, strongly nerved, the two florets about the same height, rudiment obconic. Rich or rocky woods and thickets. Not abundant but widely distributed.

Melica nitens (Scribn.) Nutt. Three-flower melic grass.

Resembling *M. mutica*; on the average, culms taller; sheaths glabrous or scaberulous; blades 7-15 mm wide; panicle more compound with several spreading branches; glumes shorter than the usually 3-flowered narrower spikelet; apex of the

second floret a little higher than that of the first; lemmas acute; rudiment mostly minute. Rocky woods. Rare. Frederick, Roanoke and Shenandoah Counties.

Microstegium Nees.

Straggling annuals with flat lanceolate blades; spikelets in pairs, alike, perfect, on an articulate rachis, 1 sessile, 1 pedicellate; racemes 1 to several, digitate or approximate, first glume sulcate.

Microstegium vimineum (Trin.) A. Camus. No common name known.

Annual; culms slender, straggling, rooting at the nodes, 50-100 cm long, freely branching; blades lanceolate, 3-8 cm long, 5-10 mm wide; racemes 2 to 6, sometimes only 1, approximate; spikelets about 5 mm long. Shaded banks and roadsides throughout the state. Introduced from Asia.

Milium L.

Moderately tall grasses with flat blades and open panicles; spikelets 1-flowered, disarticulating above the glumes; glumes equal, obtuse, membraceous, rounded on the back; lemma a little shorter than the glumes, obtuse, obscurely nerved, rounded on the back, dorsally compressed, in fruit becoming indurate, smooth and shining, the margins enclosing the lemmas.

Milium effusum L.

Smooth perennial, somewhat succulent; culms slender, erect from a bent base, 1-1.5 m tall; blades mostly 10-20 cm long, the slender branches in remote spreading or drooping pairs or fascicles, naked below; spikelet pale, 3-3.5 mm long; glumes scaberulous. Damp or rocky woods of Augusta, Bath, Highland and Rockingham Counties.

Miscanthus Anderss.

Robust perennials with long, flat blades and terminal panicles of aggregate spreading slender racemes; spikelets all alike, in pairs, unequally pedicillate along a slender continuous rachis; glumes equal, membranaceous or somewhat coriaceous; sterile lemma a little shorter than the glumes, hyaline; fertile lemma hyaline, smaller than the sterile lemma, extending into a delicate bent and flexuous awn; palea small and hyaline.

Miscanthus sinensis Anderss. Eulalia. Chinese ornamental grass.

Culms robust in large bunches, erect, 2-3 m tall; leaves numerous, mostly basal, the blades flat, as much as 1 m long, about 1 cm wide, tapering to a slender point, the margin serrate; panicle somewhat fan-shaped, consisting of numerous silky aggregate racemes, 10-20 cm long; spikelets with a tuft of silky hairs at base surrounding them and about as long as the glumes. Cultivated for ornament and now growing wild in some localities. Scattered throughout the state. Introduced from Asia.

Muhlenbergia Schreb.

Perennial with slender root stocks and flat or rolled leaves; panicles usually narrow but dense; spikelets usually 1-flowered; glumes usually shorter than lemma, often awn-tipped; lemma narrow, awned, or awnless.

- 1. Rhizomes developed, usually prominent, scaly, creeping, often branching 2
- 1'. Rhizomes wanting, the culms tufted, usually erect 9
- 2. Panicles loosely flowered, slender, much exceeding the leaves; glumes broad below, abruptly pointed, shorter

- than body of lemma 3
- 2'. Panicles usually densely flowered, tapering from base to apex 5
3. Culms slender, rather weak, becoming much branched . . . *M. brachyphylla*
- 3'. Culms erect, simple or sparingly branched 4
4. Spikelets 1.5 - 2.5 mm long; lemma apiculate; blades commonly not more than 5 - 7 mm wide *M. sobolifera*
- 4'. Spikelets 3 - 4 mm long; lemma with an awn 2 to 5 times as long as the body; blades commonly 8 mm or more wide . . . *M. tenuiflora*
5. Glumes with stiff, scabrous awn-tips, much exceeding the awnless lemma; panicles terminal on the culm or leafy branches, compact, interrupted, bristly *M. glomerata*
- 5'. Glumes acuminate, sometimes awn-tipped but not stiff and exceeding the lemma; panicles terminal and axillary, numerous, not bristly 6
6. Culms glabrous below nodes; panicles not compact, the branches ascending; plants sprawling, top heavy, the branchlets geniculate-spreading *M. frondosa*
- 6'. Culms strigose below nodes; panicles compact or, if not, the branches erect or nearly so; plants often bushy-branching but not sprawling with geniculate branchlets . . . 7
7. Callus hairs wanting; lemma nearly smooth, awnless *M. glabriflora*
- 7'. Callus hairs present; lemma pubescent below 8
8. Panicles not compactly flowered; lemma with awn as much as 10 mm or more long; some blades 10 - 15 cm or more long *M. sylvatica*
- 8'. Panicles compactly flowered or, if not, lemmas awnless; blades commonly less than 10 cm long, but sometimes longer *M. mexicana*
9. Culms decumbent and rooting at nodes *M. schreberi*
- 9'. Culms erect or spreading, not rooting at nodes 10
10. Panicle narrow, branches floriferous from base *M. cuspidata*
- 10'. Panicle open, branches naked at base 11
11. Awn of lemma less than 5 mm long; panicle usually not more than twice as long as wide at maturity, branches and pedicels stiff *M. expansa*
- 11'. Awn of lemma usually more than 10 mm long; panicle elongate, usually at least 4 times as long as wide at maturity *M. capillaris*

Muhlenbergia brachyphylla Bush. No common name known.

Perennial, with numerous slender scaly rhizomes; culms slender, sub-erect, freely branching at the middle nodes, the branches lax, glabrous or obscurely scabrous below the nodes; blades flat, spreading, scaberulous, mostly 7-15 cm long and 3-5 mm wide; panicles on filiform peduncles, very slender, lax, relatively few-flowered, mostly 8-15 cm long; spikelets, excluding the awn, about 3 mm long; the glumes about two-thirds as long, awn-tipped; lemma minutely pubescent toward the base, tapering into a slender awn 3-6 mm long, rarely shorter. Low damp to

moist woods of Fall Belt. Harvill *et al.* regard *M. brachyphylla* as a synonym of *M. bushii* Pohl.

Muhlenbergia sobolifera (Muhl.) Trin. Branched muhly.

Perennial, with numerous creeping scaly rhizomes 2-3 mm thick; culms erect, slender, solitary or few in a tuft, glabrous, 60-100 cm tall, sparingly branching, the branches erect; blades flat, spreading, scabrous, those of the main culm 5-15 cm long, 3-8 mm wide, occasionally larger, at time of flowering aggregate along the middle part of the culm; panicle slender, somewhat nodding, mostly 5-15 cm long, the distant branches appressed, floriferous from base, overlapping or the lower more distant; spikelets mostly 2-2.5 mm long; the glumes about two-thirds as long, abruptly acuminate or awn-tipped; lemma elliptic, bluntish, pubescent on the lower part, usually apiculate. Dry rocky woods and cliffs of Fall Belt, Piedmont and Valleys and Ridges.

Muhlenbergia tenuiflora (Willd.) B.S.P. Slender-flowered muhly.

Similar to *M. sobolifera* in habit; culms often more robust; blades mostly 10-18 cm long and 6-10 mm wide; panicles on the average longer; culms retrorsely puberulent at least around the nodes; sheaths puberulent or scaberulous toward the summit; spikelets (excluding the awns) 3-4 mm long; the glume about half as long, broad at the base, abruptly acuminate, scaberulous; lemma narrow, pubescent toward the base, tapering into a slender straight awn 3-10 mm long. Rocky woods mainly in central to western part of state.

Muhlenbergia glomerata (Willd.) Trin. No common name known.

Perennial from creeping branching scaly rhizomes; culms slender, erect or suberect, 30-90 cm tall, simple or with a few erect branches at base, the internodes minutely puberulent; sheaths rounded on the back; ligule minute; blades flat, 5-15 cm long, lax, 2-5 mm wide, ascending; panicle narrow, compact, lobed, mostly interrupted at base, often purplish, 3-10 cm long; spikelets 5-6 mm long; the narrow, attenuate subequal glumes stiffly awn-tipped; lemma about 3 mm long, pointed, pilose on the lower part. Sphagnum bogs, swamps and moist ground, Arlington, Fauquier and Page Counties.

Muhlenbergia frondosa (Poir.) Fern. Wirestem muhly.

Perennial, with creeping scaly rhizomes; culms often relatively stout, glabrous below the nodes, finally decumbent, often rooting at the geniculate lower nodes, freely branching from all the nodes (occasionally simple below), the branches ascending or somewhat spreading, the plants becoming top-heavy and bushy, 40-100 cm long; blades flat, scabrous, usually not more than 10 cm long, sometimes as much as 15 cm, 3-7 mm wide; panicles numerous, short exserted or partly included, terminal and axillary, the larger as much as 10 cm long (the axillary shorter), narrow, sometimes rather loose, the branches ascending, mostly densely flowered from the base; glumes 2-3 mm, rarely to 4 mm long, tapering into an awned tip, subequal or unequal, shorter than the floret, or the second glume exceeding it; lemmas 2-3 mm long, pointed, short-pilose at base. Thickets, low ground and waste places from the Fall Belt west in the state.

Muhlenbergia glabriflora Scribn. No common name known.

In habit resembling *M. frondosa*, freely branching; culms scaberulous below nodes as in *M. sylvatica*; blades numerous, short, narrow, appressed; panicles on

the average shorter and narrower than in *M. frondosa*, spikelets about as in *M. frondosa* but the lemma glabrous. Low woods in Brunswick Co.

Muhlenbergia sylvatica (Torr.) Torr. Woodland muhly.

Perennial with creeping scaly rhizomes, culms slender, retrorsely scaberulous below the nodes, rather sparingly branching from the middle and upper nodes, finally leaning, the subfiliform branches often elongate, drooping, the plant 40-100 cm tall; blades flat, lax, ascending to spreading, 0.5-18, commonly 8-15 cm long, 2-8 mm wide; panicles slender, nodding, the slender branches appressed, slightly overlapping; glumes lanceolate, acuminate or awn-tipped, 2-3 mm long; lemma slightly exceeding the glumes, pilose below, tapering into a slender awn 5-10 mm long. Moist woods and thickets scattered throughout the state.

Muhlenbergia mexicana (L.) Trin. Wirestem muhly. Mexican muhly.

Resembling *M. frondosa*, the culms erect or ascending, usually simple below, less freely branching, scaberulous below the nodes; blades lax, often 10-20 cm long, mostly 2-4 mm wide; panicles mostly long-exserted, narrow, the upper often 10-15 cm long, of numerous short appressed densely flowered somewhat aggregate branches; spikelets 2-3 mm long; glumes narrow, attenuate, awn-tipped, about equal the pointed or awn-tipped lemma; the lemma long-pilose below. Moist thickets, low woods and low open ground scattered through western part of the state.

Muhlenbergia schreberi Gmel. Nimblewill. Dropseed.

Culms slender, branching, spreading and decumbent at base, usually rooting at the lower nodes, but not forming definite creeping rhizomes, the flowering branches ascending, 10-30 cm long; blades flat, mostly less than 5 cm long, and 2-4 mm wide; panicles terminal and axillary, slender, loosely flowered, lax, nodding, 5-15 cm long; glumes minute, the first often obsolete, the second rounded, 0.1-0.2 mm long; lemma narrow, somewhat pubescent around the base, the body about 2 mm long, the slender awn 2-5 mm long. In spring and early summer the culms are short and erect with spreading blades, the plants being very different in appearance from the flowering phase of fall. Damp shady places scattered throughout the state.

Muhlenbergia cuspidata (Torr.) Rydb. Plains muhly.

Culms slender, wiry, 20-40 cm tall, erect, in dense tufts with hard, bulblike scaly bases; ligule minute; blades flat or loosely involute, erect or ascending, 1-2 mm wide; panicle narrow, somewhat spikelike, 5-10 cm long, the short branches appressed; spikelets about 3 mm long; glumes subequal, acuminate-cuspidate, about two-thirds as long as the spikelet; lemma acuminate-cuspidate, minutely pubescent. Gravelly or stony slopes, southwestern part of the state.

Muhlenbergia expansa (DC) Trin. No common name known.

Resembling *M. capillaris*, in denser tufts, the old basal sheaths forming a curly fibrous mass; blades narrow, flat, becoming involute; panicle relatively smaller, narrower, the capillary branches and branchlets mostly straight; spikelets 3.5-5 mm long; the glumes one-third to two-thirds as long, acute to acuminate; lemma scaberulous, nearly glabrous at base, awnless or with an awn 2-3 mm long, rarely longer. Moist pine barrens near the coast, Greensville County.

Muhlenbergia capillaris (Lam.) Trin. No common name known.

Perennial, in tufts; culms rather slender, erect, 60-100 cm tall; sheaths scaberulous, at least toward the summit, and with auricles mostly 3-5 mm long;

blades elongate, flat or involute, 1-4 mm wide, those of the innovations narrower, involute; panicle purple, oblong, diffuse, one-third to half the entire height of the culm, the branchlets and pedicels finally spreading; spikelets, excluding awns, 3-4 mm long; the glumes one-fourth to two-thirds as long, acute, the second often short-awned; lemma scaberulous, minutely hairy on the callus and with a delicate awn 5-15 mm long. Rocky or sandy open woods mostly in the Piedmont.

Oryzopsis Michx. Ricegrass. Mountain rice.

Mostly slender perennials with flat or often involute blades and terminal narrow or open panicles; spikelets 1-flowered, disarticulating above the glumes; glumes about equal, obtuse to acuminate; lemma indurate, usually about as long as the glumes, broad, oval or oblong, nearly terete, usually pubescent, with a short blunt, oblique callus, and a short, deciduous, sometimes bent and twisted awn; palea enclosed by the edges of the lemma.

Oryzopsis racemosa (J. E. Smith) Ricker. No common name known.

Culms tufted, from a knotty rhizome, erect, 30-100 cm tall; culm leaves several, the lowermost blades reduced, the others elongate, 5-15 mm wide, flat, tapering at both ends, rather thin, scabrous above, pubescent beneath; panicle 10-20 cm long, the branches distant, the lower spreading or reflexed at maturity, bearing a few spikelets toward the end; glumes 7-9 mm long, about 7-nerved, abruptly acuminate; lemmas slightly shorter than the glumes, sparsely pubescent, nearly black at maturity, the awn 1.5-2.5 cm long, slightly flexuous. In rocky areas under partial shade. Valleys and Ridges.

The eighth edition of Gray's Manual records *O. asperifolia* Michx. (Mountain rice) as occurring in Virginia. It differs from *O. racemosa* in having elongate basal blades and uppermost not more than 1 cm long.

Panicum L. Panicum

Annuals or perennials of various habit; usually no basal rosette formed; insufficient lateral branching to alter overall appearance; leaf blades with pronounced ribs and furrows on both sides; basal leaves similar to culm leaves; ligule a fringed or glabrous membrane, a fringe of hairs or absent; inflorescence an open or contracted panicle; spikelets all fertile.

1. Plants annual 2
- 1'. Plants perennial 8
2. Inflorescence of several more or less secund spikelike
racemes; fruit transversely rugose *P. racemosum*
- 2'. Inflorescence a more or less diffuse panicle 3
3. Spikelets tuberculate *P. verrucosum*
- 3'. Spikelets not tuberculate 4
4. First glume not more than one-fourth the length of the
spikelet, truncate or triangular-tipped *P. dichotomiflorum*
- 4'. First glume usually as much as half the length of
the spikelet, acute or acuminate 5
5. Panicles drooping; spikelets 4.5-5 mm long *P. miliaceum*
- 5'. Panicles erect; spikelets not more than 4 mm long 6
6. Panicles more than half the length of the entire plant 7
- 6'. Panicles not more than one-third the entire height
of the plant 8

7. Panicles narrow, usually less than half as broad as long . . . *P. flexile*
- 7'. Panicles as broad as long *P. capillare*
8. Culms relatively stout; blades about 1 cm wide;
spikelets turgid *P. gattingeri*
- 8'. Culms slender; blades not more than 6 mm wide;
spikelets not turgid *P. philadelphicum*
9. Spikelets short-pedicel along one side of the
rachises, forming spikelike racemes *P. hemitomon*
- 9'. Spikelets in open or sometimes contracted or
congested panicles 10
10. Sterile palea enlarged and indurate at maturity,
expanding the spikelet *P. hians*
- 10'. Sterile palea, if present, not enlarged 11
11. Plants with conspicuous creeping scaly rhizomes 12
- 11'. Plants without creeping scaly rhizomes 16
12. Panicle elongate, strongly contracted 13
- 12'. Panicle diffuse or only slightly contracted 14
13. Culms rarely 1 m tall, solitary from nodes of
horizontal rhizome *P. amarum*
- 13'. Culms 1-2 m tall, in dense tufts *P. amarulum*
14. Spikelets 3.5-5 mm long; culms 1-2 (-3) m tall *P. virgatum*
- 14'. Spikelets up to 3.8 mm long; culms up to 1 m tall 15
15. Panicles open; spikelets 3.4-3.8 mm long *P. anceps*
- 15'. Panicles more or less contracted; spikelets not more
than 2.8 mm long *P. rhizomatum*
16. Ligule ciliate; basal leaves half as long as culm or more;
panicle much exceeding upper leaves 17
- 16'. Ligule erose or lacerate, not ciliate; upper leaves
usually nearly equalling the terminal panicle 18
17. Spikelets up to 2.7 mm long, the first glume less than
half that length; ligule 2-3 mm long *P. longifolium*
- 17'. Spikelets 3-3.5 mm long; first glume two-thirds to
three-fourths that length; ligule less than 1 mm long *P. combsii*
18. Fruit stipitate; spikelets 2.5-2.8 mm long, conspicuously
secund *P. stipitatum*
- 18'. Fruit not stipitate; spikelets not conspicuously secund . . . 19
19. Spikelets up to 2.2 mm long; panicle branches ascending
or spreading *P. agrostoides*
- 19'. Spikelets about 2.5 mm long; panicle branches erect or
nearly so *P. condensum*

Panicum racemosum L. Brown-top millet.

Culms erect or spreading from a decumbent base, 30-100 cm tall, sometimes pubescent below the panicle or hispid below the appressed pubescent nodes; sheaths glabrous to papillose-hispid; blades narrow, pubescent; panicles compact; raceme suberect; pedicels bristly; spikelets glabrous to finely pubescent, about 3 mm long, tawny or dull brown. Waste ground of Greensville, Lunenburg and Prince George Counties. Sometimes planted for wildlife.

Panicum verrucosum Muhl. No common name known.

Culms 20-150 cm long, slender, weak, decumbent at base, usually with stilt roots, bright green, at first erect, later widely spreading; blades thin, flat, lax, 5-20 cm long, 4-10 mm wide; panicles with divaricate capillary branches 5-30 cm long, about as wide, diffuse, small panicles often produced at lower nodes; spikelets mostly in pairs, toward the ends of the capillary branches, 1.8-2.1 mm long, elliptic-obovate, subacute, roughened with small warts. Wet, mostly shady soil in eastern part of the state.

Panicum dichotomiflorum Michx. Fall panicum.

Culms ascending or spreading from a geniculate base, 50-100 (-200) cm long; ligule a dense ring of white hairs 1-2 mm long; blades scaberulous and sometimes sparsely pilose on upper surface, 10-50 cm long, 3-20 mm wide, the white midrib usually prominent; panicles terminal and axillary, mostly included at base, 10-40 cm long or more, main branches ascending; spikelets narrowly oblong-ovate, 2-3 mm long, acute. Moist ground, along streams and a weed in waste places and cultivated soil throughout the state.

Panicum miliaceum L. Broom corn millet. Hog millet. Proso.

Culms stout, erect or decumbent at base, 20-100 cm tall; blades more or less pilose on both surfaces or glabrate, as much as 30 cm long and 2 cm wide, rounded at base; panicles usually more or less included at base, 10-30 cm long, usually nodding, rather compact, the numerous branches ascending, very scabrous, spikelet-bearing toward the ends; spikelets 4.5-5 mm long, ovate, acuminate, strongly many-nerved; first 3 mm long, stramineous to reddish brown. Waste places, introduced or escaped from cultivation.

Panicum flexile (Gattinger) Scribn. No common name known.

Culms slender, erect, much-branched from the base, 20-70 cm tall, somewhat hispid below, the nodes pubescent; blades erect but not stiff, glabrous or sparsely hispid, up to 30 cm long, 2-6 mm wide; panicle relatively few-flowered, oblong, narrow, 10-20 cm long, about one-third as wide; spikelets 3.1-3.5 mm long. Sandy, mostly damp soil, meadows and open woods scattered throughout the state.

Panicum capillare L. Witchgrass. Old witchgrass.

Culms erect or somewhat spreading at base, 20-80 cm tall, papillose-hispid to nearly glabrous; sheaths hispid; blades 10-25 cm long, 5-15 mm wide, hispid on both surfaces; panicles densely flowered, very diffuse, often half the length of the entire plant, included at the base until maturity, the branches finally divaricately spreading, the whole panicle breaking away and rolling before the wind; spikelets 2-2.5 mm long. Open ground and waste places, a weed in cultivated ground in scattered locations throughout the state.

Panicum gattingeri Nash. No common name known.

Culms at first erect, soon decumbent and rooting at the lower nodes, papillose-hispid, in robust specimens up to 1 m long; blades 6-10 mm wide, more or less hispid or nearly glabrous; panicles numerous, terminal and axillary, oval or elliptic in outline, the terminal 10-15 cm long, the lateral smaller; spikelets 2 mm long. Open ground and waste places, often a weed in cultivated soil in Arlington, Fauquier, Page, Montgomery, and Roanoke Counties.

Panicum philadelphicum Bernh. ex Trin. (= *P. tuckermanni* Fern.) No common name known.

Plants light yellowish green; culms slender, usually erect, 15-50 cm tall, papillose-hispid to nearly glabrous, more or less zigzag at base; blades usually erect, 5-15 cm long, 2-6 mm wide, rather sparsely hirsute; panicles 10-20 cm long, few flowered, the branches solitary, rather stiffly ascending, the axillary pulvini hispid; spikelets 1.7-2 mm long, mostly in twos at ends of branchlets. Dry open or sandy ground scattered throughout the state.

Panicum hemitomon Schult. Maidencane.

With extensively creeping rhizomes, often producing numerous sterile shoots with overlapping, sometimes densely hirsute, sheaths; culms 50-150 cm tall, usually hard; sheaths of fertile culms usually glabrous; blades 10-25 cm long, 7-15 mm wide, usually scabrous on upper surface and smooth beneath; panicle 15-30 cm long, branches erect, the lower distant, the upper approximate, 2-10 cm long; spikelets 2.4-2.7 mm long, lanceolate, acute; first glume about half the length of the spikelet; fruit less rigid than usual in the genus, the apex of the palea scarcely enclosed. Moist soil along riverbanks and ditches, borders of lakes and ponds, often in the water, sometimes a weed in moist cultivated fields in Augusta, Isle of Wight and Sussex Counties and City of Chesapeake.

Panicum hians Ell. No common name known.

Culms 20-60 cm tall, mostly erect, sometimes more or less decumbent or prostrate with erect branches; blades 5-15 cm long, 1-5 mm wide, flat or folded, pilose on upper surface near base; panicles 5-20 cm long, usually loose and open, the primary branches few, slender, distant, spreading or drooping, the branchlets borne on the upper half or towards the ends only; spikelets in more or less secund clusters, 2.2-2.4 mm long, at maturity about twice as thick as wide. Damp soil along ponds and streams of Greenville, Southampton and Sussex Counties. Gould and Shaw regard this taxon as *Steinchisma hians* (Ell.) Nash ex Small.

Panicum amarum Ell. No common name known.

Glaucous and glabrous throughout; culms solitary from extensively creeping rhizomes, 30-100 cm tall; blades thick, 10-30 cm long, 5-12 mm wide, flat, involute toward the tip, the margins smooth; panicle one-fourth to one-third the height of the plant, not more than 3 cm wide, the branches appressed; spikelets 5-6.5 mm long, acuminate. Sandy seashores and coast dunes of Coastal Plain.

Panicum amarulum Hitchc. & Chase. No common name known.

Culms as much as 1 cm thick, in large branches as much as 1 m across, 1-2 m tall, glaucous; rhizomes vertical or ascending; blades 20-50 cm long, 5-12 mm wide, more or less involute, pilose on the upper surface near base; panicle large, rather compact, 5-10 cm wide, slightly nodding, densely flowered; spikelets 4.3-5.5 mm long, acuminate. Sandy shores and coast dunes of Accomack and Northampton Counties and Cities of Virginia Beach and Newport News.

Panicum virgatum L. Switchgrass.

Plants usually in large tufts, green or glaucous, with numerous scaly creeping rhizomes; culms erect, tough and hard, 1-2 (-3) m tall; sheaths glabrous; blades 10-60 cm long, 3-5 mm wide, flat, glabrous, or sometimes pilose above near base, rarely pilose all over; panicle 15-50 cm long, open, sometimes diffuse; spikelets 3.5-5 mm long, acuminate; first glumes clasping, two-thirds to three-fourths as long as spikelet, acuminate or cuspidate; fruit narrowly ovate, the margins of the lemma

inrolled only at base. Prairies and open ground, open woods, and brackish marshes mostly in eastern and northern part of the state.

Panicum anceps Michx. No common name known.

Culms 50-100 cm tall, with numerous scaly rhizomes; sheaths glabrous or pilose; blades elongate, 4-12 mm wide, pilose above near base; panicles 15-40 cm long, the slender, remote branches somewhat spreading, bearing short mostly appressed branchlets with rather crowded somewhat curved subsecund spikelets, set obliquely on their pedicels; spikelets 3.4-3.8 mm long. Moist sandy soil throughout the state.

Panicum rhizomatum Hitchc. & Chase. No common name known.

Resembling *P. anceps*; culms less robust, the rhizomes more slender and numerous; sheaths densely to sparsely villose, especially at the summit; blades usually pubescent on both surfaces; panicles more or less contracted; spikelets 2.4-2.8 mm long. Moist sandy woods and savannas of Northampton, Southampton, and Dinwiddie Counties and Cities of Norfolk and Virginia Beach.

Panicum longifolium Torr. No common name known.

Culms rather slender, 35-80 cm tall, in dense tufts, usually surrounded by basal leaves nearly half as long; sheaths usually villose near summit; ligule fimbriate-ciliate, 2-3 mm long; blades elongate, 2-5 mm wide, pilose on upper surface near base; lateral panicles few or none, the terminal 10-25 cm long, the branches slender, ascending; spikelets 2.4-2.7 mm long. Moist sandy ground of Augusta County and Coastal Plain.

Panicum combsii Scribn. & Ball. No common name known.

Resembling *P. longifolium*; sheaths glabrous or nearly so; ligule less than 1 mm long; blades on the average shorter; spikelets 3-3.5 mm long, acuminate. Margins of ponds and wet woods, City of Virginia Beach.

Panicum stipitatum Nash. No common name known.

Resembling *P. agrostoides*; often purple-tinged throughout, especially the panicles; sheaths much overlapping, the blades usually equalling or exceeding the terminal panicle; panicles usually several to a culm, 10-20 cm long, narrow, densely flowered, the numerous stiff branches ascending, with numerous divaricate branchlets, mostly on lower side; spikelets 2.5-2.8 mm long, often curved at the tip. Moist soil of Accomack, Arlington, Fairfax, Fauquier, Northampton, Roanoke and Shenandoah Counties.

Panicum agrostoides Spreng. No common name known.

In dense clumps from a short crown, with numerous shortleaved innovations at base; culms 50-100 cm tall; blades erect, folded at base, flat above, 20-50 cm long, 5-12 mm wide; panicles terminal and axillary, 10-30 cm long, half to two-thirds as wide, sometimes more diffuse, the densely flowered branchlets mostly on the underside of the branches, the pedicels usually bearing at the summit one to several delicate hairs; spikelets about 2 mm long. Wet meadows and shores of Accomack, Augusta, Charles City, James City, Northampton, Shenandoah, Southampton and York Counties and the City of Virginia Beach. Harvill *et al.* (1986) list this as *P. rigidulum* Nees.

Panicum condensum Nash. No common name known.

Resembling *P. agrostoides*; culms on the average taller; blades often sparsely pilose on the upper side at the folded base; panicles 10-25 cm long, rarely more

than 5 cm wide, the long branches erect, naked at base, with appressed branchlets bearing crowded spikelets, the pedicels not pilose; spikelets 2.2-2.5 mm long. Borders of streams and ponds and in wet places in Arlington, James City, Stafford and York Counties and City of Virginia Beach.

Parapholis C. E. Hubb.

Low annuals, with slender, cylindric spikes; spikelets 1- or 2-flowered, embedded in the cylindric articulate rachis and falling attached to the joints; glumes 2, placed in front of the spikelet and enclosing it, coriaceous, 5-nerved, acute, symmetric, appearing like halves of a single split glume; lemma with its back to the rachis, smaller than the glumes, hyaline, 1-nerved; palea a little shorter than the lemma, hyaline.

Parapholis incurva (L.) C. E. Hubb. Sickie grass.

Culms tufted, decumbent at base, 10-20 cm tall; blades short, narrow; spike 7-10 cm long, cylindric, curved; spikelets 7 mm long, pointed. Mud flats and salt marshes along the coast on the Eastern Shore.

Paspalum L.

Perennial or annual; inflorescence of one or more racemes borne at summit of culm or in axils of uppermost leaves; spikelets one-flowered, plano-convex, in two rows on one side of elongated rachis; first glume usually absent; lemma and palea hardened; back of fertile lemma against rachis.

1. Rachis foliaceous, broad and winged 2
- 1'. Rachis not foliaceous nor winged 3
2. Racemes falling from the axis, rachis extending beyond uppermost spikelets *P. fluitans*
- 2'. Racemes persistent on axis; rachis with a spikelet at apex *P. dissectum*
3. Racemes 2, conjugate or nearly so at summit of culm, rarely a third below 4
- 3'. Racemes 1 to many, racemose on axis, not conjugate 5
4. Spikelets elliptic to narrowly ovate *P. distichum*
- 4'. Spikelets suborbicular, broadly ovate or obovate *P. notatum*
5. First glume developed on at least one of the pair of spikelets *P. bifidum*
- 5'. First glume normally wanting 6
6. Racemes terminal and axillary 7
- 6'. Racemes terminal on primary culm on leafy branches, no truly axillary racemes 13
7. Spikelets usually 1.5-1.7 mm long, not more than 1.8 or 1.9 mm long 8
- 7'. Spikelets 2-2.5 mm long (1.8-1.9 mm in *P. ciliatifolium*) 10
8. Blades conspicuously ciliate, otherwise nearly glabrous *P. longepedunculatum*
- 8'. Blades and sheaths conspicuously pubescent throughout 9
9. Culms slender, erect or suberect; foliage not aggregate at base; blades suberect, usually not more than 5 mm wide *P. setaceum*

- 9'. Culms stouter, mostly spreading, foliage more or less aggregate at base; blades spreading, usually more than 5 mm wide *P. debile*
10. Foliage, except margins, glabrous or nearly so *P. ciliatifolium*
- 10'. Foliage conspicuously pubescent 11
11. Culms erect or nearly so *P. pubescens*
- 11'. Culms widely spreading or prostrate 12
12. Foliage coarsely hirsute; culms relatively stout, widely spreading *P. supinum*
- 12'. Foliage finely puberulent; culms usually prostrate in dense grayish-olivaceous mats *P. psammophilum*
13. Spikelets conspicuously silky-ciliate around margin 14
- 13'. Spikelets not ciliate 15
14. Racemes commonly 3 to 5; culms geniculate at base *P. dilatatum*
- 14'. Racemes commonly 12 to 18, culms erect *P. urvillei*
15. Fruit dark brown and shining *P. boscianum*
- 15'. Fruit pale to stramineous 16
16. Plants robust, 1-2 m tall *P. floridanum*
- 16'. Plants not robust, if more than 1 m tall, culms relatively slender 17
17. Spikelets suborbicular or broadly obovate or broadly oval 18
- 17'. Spikelets elliptic to oval or obovate *P. pubiflorum*
18. Spikelets solitary; glume and sterile lemma firm 19
- 18'. Spikelets paired and solitary in same raceme 21
19. Spikelets orbicular, 3-3.2 mm long, scarcely one-third as thick, blades usually equalling base of panicle or overtopping it *P. circulare*
- 19'. Spikelets longer than broad, more than one-third as thick, panicle usually much exceeding blades 20
20. Sheaths and blades most conspicuously pilose *P. longipilum*
- 20'. Sheaths and blades from glabrous to sparsely pilose *P. laeve*
21. Spikelets 2.2-2.5 mm long; foliage not conspicuously villose *P. praecox*
- 21'. Spikelets 2.7-3.4 mm long; lower sheaths and blades mostly conspicuously villose at least at base *P. lentiferum*

Paspalum fluitans (Ell.) Kunth. Water paspalum.

Annual aquatic; culms mostly submerged, rooting at the nodes, 30-100 cm long; sheaths glabrous or pilose, with an erect auricle 1-5 mm long on each side, the sheaths of the floating branches inflated, commonly long-hirsute and purple-spotted; blades usually 10-20 cm long, 10-15 mm wide (sometimes 25 cm long and 2.5 cm wide); panicles mostly 10-15 cm long, of numerous ascending, spreading or recurved racemes, 3-8 cm long, falling entire, the rachis 1.3-2 mm wide; spikelets solitary, elliptic, 1.3-1.8 mm long, acute or acuminate, pilose with delicate hairs, sometimes obscurely so, the sterile lemma with a V-shaped pink marking at base.

Floating in sluggish streams or standing water or creeping in wet places of Brunswick, Chesterfield, Cumberland, Fairfax and Southampton Counties.

Paspalum dissectum (L.) L. No common name known.

Glabrous, olive green, creeping, freely branching, the flowering branches ascending, 20-64 cm long; blades thin, 3-6 cm long, 4-5 mm wide; panicles terminal and axillary, the racemes 2 to 4, usually erect, 2-3 cm long; rachis 2-3 mm wide; spikelets solitary, obovate, subacute, 2 mm long. In muddy and sandy banks of ponds and ditches or in shallow water of Coastal Plain.

Paspalum distichum L. Knotgrass.

Flowering culms 8-60 cm tall; sheaths usually overlapping; sometimes with extensively creeping stolons with pubescent nodes; blades 2.5-15 cm long, 3-8 mm wide, tapering to an involute apex; racemes 2-7 cm long, commonly incurved; spikelets 2.5-3.5 mm long, elliptic, abruptly acute, pale green; first glume frequently well developed, second glume appressed-pubescent, the midnerve in glume and sterile lemma well developed. Ditches and wet, rarely brackish places. Isle of Wight County, Cities of Chesapeake, Suffolk, and Virginia Beach.

Paspalum notatum Flügg. Bahia grass.

Culms 15-50 cm tall from a short, stout, woody, horizontal rhizome; blades flat or folded; racemes recurved-ascending, usually 4-7 cm long; spikelets ovate to obovate, 3-3.5 mm long, smooth and shining. Introduced and sometimes cultivated.

Paspalum bifidum (Bertol.) Nash. No common name known.

Culms erect from short rhizomes, 50-120 cm tall; blades flat, 10-50 cm long, 3-14 mm wide, villose to nearly glabrous; racemes usually 3 or 4, at first erect, 4-16 cm long; rachis slender, subflexuous; spikelets distant to irregularly approximate, elliptic-obovate, 3.3-4 mm (rarely to 4.2 mm) long; second glume and sterile lemma conspicuously nerved. Sandy pine and oak woods, occasionally in hammocks, nowhere common, on the Coastal Plain.

Paspalum longepedunculatum LeConte. No common name known.

Culms slender, ascending or suberect, 25-80 cm tall; leaves mostly aggregate at the base, the sheaths ciliate on the margin; blades usually folded at base, 4-10 cm long, rarely longer, 3-8 mm wide, stiffly papillose-ciliate on the margin, the hairs 1.5-3 mm long; racemes on very slender finally elongate peduncles, 1 or 2, rarely 3 on the primary, 1 on the axillary peduncles; racemes arching, 3-8 cm long; spikelets about 1.5 mm long, elliptic-obovate, glabrous. Sandy soil, mostly in low pine land or flat woods.

Paspalum setaceum Michx. Thin paspalum.

Culms slender, erect, usually 30-50 cm tall; sheaths pilose; blades rather firm, erect or nearly so, linear, about 10-12 cm long, 2-6 mm wide, densely pilose on both surfaces and papillose-ciliate on the margin; racemes on slender peduncles, solitary or sometimes 2, arching, 5-7 cm long; spikelets elliptic-obovate, about 1.5 mm long, glabrous or minutely pubescent. Sandy soil, usually open woods, mostly on or near the Coastal Plain.

Paspalum debile Michx. No common name known.

Differing from *P. setaceum* in the stouter, more spreading culms, the foliage more crowded at the base, densely grayish villose, the blades on the average wider, racemes more commonly 2; spikelets 1.8-1.9 mm long, pubescent. Sandy, mostly dry soil, barrens and flat woods.

Paspalum ciliatifolium Michx. Fringeleaf paspalum.

Culms erect to spreading, 35-90 cm tall; sheaths glabrous or the lower puberulent; blades 10-35 cm long, 7-20 mm wide (rarely larger), usually strong ciliate along the margin and glabrous otherwise; racemes 1 to 3, usually 7-10 cm long; spikelets about 2 mm long, suborbicular, the glumes often minutely pubescent. Mostly sandy, open ground or open woods.

Paspalum pubescens Muhl. Hairy paspalum.

Culms ascending, 45-90 cm tall, often pilose at the summit; sheaths usually pilose toward the summit, blades 8-20 cm long, 2-10 mm wide (rarely larger), pilose on both surfaces; racemes 1 to 3, 4-17 cm long; spikelets about 2 mm long, suborbicular, usually glabrous. Open ground or open woods, common in old fields and pastures, especially in sandy regions.

Paspalum supinum Bosc ex Poir. No common name known.

Culms relatively stout, widely spreading, 30-90 cm tall; sheaths usually hirsute; blades 15-25 cm long, 8-15 mm wide, hirsute; racemes usually 2 to 4, rarely to 6, 4-10 cm long; spikelets elliptic-obovate, 2 mm long, glabrous, or the glume minutely pubescent. Dry, sandy open ground and old fields of the Coastal Plain.

Paspalum psammophilum Nash. No common name known.

Forming dense grayish-olivaceous mats, the culms usually prostrate, 25-100 cm long; sheaths appressed-pubescent; blades 4-16 cm long, 4-11 mm wide, densely appressed-pubescent; racemes 1 to 3, commonly 2, 4-9 cm long, the axillary ones wholly or partially included in the sheaths; spikelets suborbicular, 2 mm long, the glume densely pubescent. Dry sandy soil, mostly near the coast, Arlington and James City Counties.

Paspalum dilatatum Poir. Dallis grass. Paspalum-grass. Water-paspalum. Water grass. Paspalum.

Culms tufted, leafy at base, mostly 50-150 cm tall, ascending or erect from a decumbent base; blades 10-25 cm long, 3-12 mm wide, racemes usually 3 to 5, spreading, 6-8 cm long; spikelets ovate-pointed, 3-3.5 mm long, fringed with long white silky hairs and sparsely silky on the surface. In low ground, from rather dry prairie to marshy meadows. Often used in pastures. General, especially in the Piedmont. Introduced from Uruguay or Argentina.

Paspalum urvillei Steud. Vasey grass. Vaseygrass.

Culms in large clumps, erect, mostly 1-2 m tall; lower sheaths coarsely hirsute or occasionally glabrous; blades mostly elongate, 3-15 mm wide, pilose at base; panicle erect, 10-40 cm long, of about 12 to 20 rather crowded, ascending racemes, 7-14 cm long; spikelets 2.2-2.7 mm long, ovate, pointed, fringed with long white silky hairs, the glume appressed-silky. Along ditches and roadsides and in wasteground, mostly in rather moist soil of Coastal Plain and Piedmont. Introduced from South America.

Paspalum boscianum Flüge. Bull paspalum.

Rather succulent annual, branching at base and commonly from the middle nodes, usually conspicuously brownish purple, glabrous as a whole; culms 40-60 cm long, ascending or widely spreading; sheaths broad, loose; blades 10-14 cm long, 8-15 mm wide, papillose-pilose on upper surface near base; racemes 4 to 12, usually 4-7 cm long; rachis 2-2.5 mm wide; spikelets crowded, obovate-orbicular, 2-2.2 mm long, glabrous, rust brown at maturity. Moist or wet open ground, along ditches

and ponds, sometimes a weed in cultivated fields mostly in the Coastal Plain but also Fall Belt and Piedmont.

Paspalum floridanum Michx. Florida paspalum.

Culms solitary or few from short stout scaly rhizomes, 1-2 m tall, sheaths villose to nearly glabrous, blades firm, flat or folded, 15-50 cm long, 4-10 mm wide, usually villose at least on the upper surface toward base; racemes usually 2 to 5, 4-12 cm long; spikelets crowded, oval, about 4 mm long. Low moist sandy soil, pine woods, flatwoods, savannas of Coastal Plain and Piedmont.

Paspalum pubiflorum Rupr. ex Fourn. Hairyseed paspalum.

Culms decumbent at base, 40-100 cm tall, sheaths, at least the lower, sparsely papillose-pilose, blades flat, usually 10-15 cm long, 6-14 mm wide, usually with a few stiff hairs at the rounded base; racemes mostly 3 to 5, 2-10 cm long, rather thick, erect to spreading, the rachis 1.2-2 mm wide; spikelets obovate, pubescent, about 3 mm long. Moist open ground, banks, low woods, along streams scattered throughout the state.

Paspalum circulare Nash. No common name known.

Culms in dense leafy clumps, 30-80 cm tall; sheaths pilose to nearly glabrous; blades mostly erect, commonly about equalling the inflorescence, 15-30 cm long, 5-10 mm wide, usually pilose on upper surface; racemes 2 to 7, mostly suberect, 5-12 cm long; spikelets nearly orbicular, about 3 mm long. Fields, meadows and open waste ground scattered throughout the state.

Paspalum longipilum Nash. Long-haired paspalum.

Similar to *P. laeve*, usually less leafy at base, sheaths and blades pilose; racemes somewhat more lax than in *P. laeve*. Dry, mostly sandy soil, savannas, open woods and wet pine barrens of Coastal Plain, Fall Belt and Piedmont.

Paspalum laeve Michx. Smooth paspalum. Field paspalum.

Culms erect or ascending, leafy at base, 40-100 cm tall; sheaths keeled, glabrous or nearly so; blades usually folded at base, flat or folded above, 5-30 cm long, 3-10 mm wide, glabrous to ciliate or sparsely pilose on upper surface or sometimes toward base beneath; racemes usually 3 or 4, spreading, 3-10 cm long; spikelets broadly oval, 2.5-3 mm long. Meadows, old fields, open woods and waste ground throughout the state.

Paspalum praecox Walt. No common name known.

Culms erect from short scaly rhizomes, 50-100 cm tall; sheaths keeled, glabrous, or the lower villose; blades 15-25 cm long, 3-7 mm wide, glabrous or nearly so; racemes usually 4 to 6, ascending to arcuate-spreading, 2-7 cm long, the common axis very slender; rachis about 1.5 mm wide, purplish; spikelets usually solitary and paired in each raceme, strongly flattened, suborbicular, 2.2-2.8 mm long, the glume and sterile lemma thin and fragile. Wet pine barrens, borders of cypress swamps, moist places in flat woods of Greenville and Sussex Counties, City of Suffolk.

Paspalum lentiferum Lam. No common name known.

Similar to *P. praecox*; culms more robust, sometimes as much as 150 cm tall, sheaths less strongly keeled; blades usually more or less pilose; racemes usually 4 or 5; spikelets 2.7-3.4 mm long, broadly oval. Moist pine barrens, borders of flatwoods and cypress swamps of Greenville and Sussex Counties.

Pennisetum Rich.

Annuals or perennials, often branched, with usually flat blades and dense spikelike panicles; spikelets solitary or in groups of 2 or 3, surrounded by an involucre of bristles, these not united except at the very base, often plumose, falling attached to the spikelets; first glume shorter than the spikelet, sometimes minute or wanting; second glume shorter than or equalling the sterile lemma; fertile lemma chartaceous, smooth, margin thin and enclosing palea.

Pennisetum glaucum (L.) R. Br. Pearl millet. Cattail millet. Bullrush millet.

Annual, culms robust, up to 2 m tall, densely villose below panicle; blades flat, cordate, up to 1 m long and 5 cm wide; panicle cylindric, stiff, very dense, up to 40 - 50 cm long and 2 - 2.5 cm thick, pale, bluish-tinged, or sometimes tawny, the stout axis densely villose; spikelets short-pedicel, 2 in a peduncled fascicle, 3.5-4.5 mm long, obovate, turgid, the mature grain protruding from the hairy-margined palea and lemma. Cultivated since prehistoric times for human food and forage. Prince Edward County

Phalaris L. Canary grass.

Annuals or perennials, with numerous flat blades and narrow or spikelike panicles; spikelets laterally compressed, with 1 terminal perfect floret and 2 sterile lemmas below, the rachilla disarticulating above the glumes, the usually inconspicuous sterile lemmas falling closely appressed to the fertile floret; glumes equal, boat-shaped, often winged on the keel; sterile lemmas reduced to 2 small, usually minute scales, fertile lemma coriaceous, shorter than glumes, enclosing the faintly 2-nerved palea.

1. Plants perennial *P. arundinacea*
- 1'. Plants annual 2
2. Glumes broadly winged; panicle ovate or short-oblong . . . *P. canariensis*
- 2'. Glumes wingless or nearly so; panicles oblong or linear . . . *P. caroliniana*

Phalaris arundinacea L. Reed canary grass.

Perennial, with creeping rhizomes, glaucous; culms erect, 60-150 cm tall; panicle 7-18 cm long, narrow, the branches spreading during anthesis, the lower as much as 5 cm long; glumes about 5 mm long, narrow, acute, the keel scabrous, very narrowly winged; fertile lemma lanceolate, 4 mm long, with a few appressed hairs, sterile lemmas villose, 1 mm long. Marshes, riverbanks, and moist places, Blue Ridge and Ridges and Valleys.

Phalaris canariensis L. Canary grass.

Annual; culms erect, 30-60 cm tall; panicle ovate to oblong-ovate, dense, 1.5-4 cm long; spikelets broad, imbricate, pale with green stripes; glumes 7-8 mm long, abruptly pointed, the green keel with a prominent pale wing, broadened upward; fertile lemma 5-6 mm long, acute, densely appressed; sterile lemmas at least half as long as fertile. Waste places of Coastal Plain, Blue Ridge, Alleghany Valleys and Ridges. This is the canary seed of commerce.

Phalaris caroliniana Walt. Carolina canary grass.

Annual; culms erect, 30-60 or more tall; panicle oblong, 2-6 cm long, occasionally longer, tapering to each end; glumes 5-6 mm long, rather abruptly narrowed to an acute apex, the keel scabrous and narrowly winged above from below the middle; fertile lemma lanceolate, acute, appressed-pubescent, about 3.5-4 mm long; the sterile lemma one-third to half as long. Old fields, sandy soil and moist places, Coastal Plain.

Phleum L. Timothy.

Annuals or perennials with erect culms, flat blades, and dense, cylindric panicles; spikelets 1-flowered, laterally compressed, disarticulating above the glumes; glumes equal, membranaceous, keeled, abruptly mucronate or awned or gradually acute; lemma shorter than glumes, hyaline, broadly truncate, 3- to 5-nerved; palea narrow, nearly as long as lemma.

Phleum pratense L. Timothy. Herd's grass. Cat's tail.

Culms 50-100 cm tall, from a swollen or bulb-like base, forming large clumps; blades elongate, mostly 5-18 mm wide; panicle cylindric, usually 5-10 cm long, spikelets crowded, spreading; glumes about 3.5 mm long, truncate with a stout awn 1 mm long, pectinate-ciliate on keel. Planted for hay especially in Piedmont and Mountains but escaped from cultivation along roadsides and in fields and waste places. Native of Eurasia.

Phragmites Trin.

Perennial reeds with broad, flat, linear blades and large terminal panicles; spikelets several-flowered, the rachilla clothed with long silky hairs, disarticulating above glumes and at base of each segment between florets, the lowest floret staminate or neuter; glumes 3-nerved or the upper 5-nerved, lanceolate, acute, unequal, the first about half as long as the upper, the second shorter than the florets; lemmas narrow, long-acuminate, glabrous, 3-nerved, the florets successively smaller, the summits of all about equal; palea much shorter than lemma.

Phragmites communis Trin. (= *P. australis* (Cav.) Trin. ex Steud.) Common reed.

Culms erect, 2-4 m tall with stout creeping rhizomes and often also with stolons; blades flat, 1-5 cm wide; panicle tawny or purplish, 15-40 cm long, the branches ascending, rather densely flowered; spikelets 12-15 mm long, the florets exceeded by the hairs of the rachilla. Marshes, banks of lakes and streams, and around springs, Fall Belt, Coastal Plain and Piedmont.

Poa L. Bluegrass

Low or rather tall slender annuals or usually perennials with spikelets in open or contracted panicle, the relatively narrow blades flat, folded or involute, ending in a boat-shaped tip; spikelets 2- to several-flowered, the rachilla disarticulating above glumes and between florets, the uppermost floret reduced or rudimentary; glumes acute, keeled, somewhat unequal, the first usually 1-nerved, the second usually 3-nerved; lemmas somewhat keeled, acute or acutish, rarely obtuse, awnless, membranaceous, often somewhat scarious at the summit, 5-nerved (the pair between the keel and marginal nerves rarely obsolete), nerves sometimes pubescent, callus or base of lemma in many species with scant to copious cottony hairs termed "web".

- | | |
|---|-----------------------|
| 1. Plants annual | 2 |
| 1'. Plants perennial | 3 |
| 2. Lemmas with webby hairs at base, distinctly 3-nerved,
intermediate nerves obscure; anthers 0.1 to 0.2 mm long . . | <i>P. chapmaniana</i> |
| 2'. Lemmas not webbed at base, distinctly 5-nerved,
anthers 0.5 to 1 mm long | <i>P. annua</i> |
| 3. Creeping rhizomes present | 4 |
| 3'. Creeping rhizomes wanting | 7 |

- 4. Culms strongly flattened, 2-edged *P. compressa*
- 4'. Culms terete or slightly, flattened, not 2-edged 5
- 5. Plants dioecious *P. arachnifera*
- 5'. Plants not dioecious, florets perfect 6
- 6. Lower panicle branches in a whorl of usually 5;
blades mostly shorter than culm *P. pratensis*
- 6'. Lower panicle branches usually in twos, spreading,
spikelet-bearing near the ends, blades about as
long as culm *P. cuspidata*
- 7. Lemmas webbed at base 8
- 7'. Lemmas not webbed at base *P. autumnalis*
- 8. Lemmas glabrous, or keel sometimes pubescent 9
- 8'. Lemmas pubescent on keel and marginal nerves 12
- 9. Sheaths retrorsely scabrous *P. trivialis*
- 9'. Sheaths glabrous 10
- 10. Lemma villose on keel; panicle branches mostly in fours
and fives *P. alsodes*
- 10'. Lemmas glabrous on keel; panicle branches mostly in
twos or threes 11
- 11. Lemmas obtuse *P. languida*
- 11'. Lemmas acute *P. saltuensis*
- 12. Lower panicle branches distinctly reflexed at maturity . . . *P. sylvestris*
- 12'. Lower panicle branches not reflexed 13
- 13. Intermediate nerves of lemma distinct *P. wolfii*
- 13'. Intermediate nerves of lemma obscure 14
- 14. Florets usually converted into bulblets with dark
purple base; culms swollen and bulblike at base *P. bulbosa*
- 14'. Florets normal; culms not bulblike at base 15
- 15. Glumes narrow, acuminate, about as long as first lemma;
ligule very short *P. nemoralis*
- 15'. Glumes lanceolate, acute, shorter than first
lemma; ligules rather prominent, those of the culm
leaves 1-3 mm or more long *P. palustris*

Poa chapmaniana Scribn. No common name known.

Plant drying pale to tawny; culms densely tufted, slender, 10-30 cm tall; blades 1-1.5 mm wide; panicle oblong-pyramidal, 3-8 cm long, open, the lower branches spreading; spikelets 3-4 mm long, mostly 3- to 5-flowered; glumes 2 and 2.5 mm long; lemmas about 2 mm long, webbed at base, strongly pubescent on keel and lateral nerves, intermediate nerves obscure; anthers 0.1-0.2 mm long. Open ground and cultivated fields, Coastal Plain, Piedmont.

Poa annua L. Annual bluegrass

Tufted, bright green, erect to spreading, sometimes rooting at lower nodes, usually 5-20 cm tall, sometimes taller, forming mats; culms flattened, blades soft, lax, mostly 1-3 mm wide; panicles pyramidal, open, 3-7 cm long; spikelets crowded, 3- to 6-flowered, about 4 mm long; first glume 1.5-2, second 2-2.5 mm long; lemmas not webbed at base, distinctly 5-nerved, more or less pubescent on lower half of all nerves, the long hairs on lower part of keel sometimes simulating a web; anthers 0.5-1

mm long. Introduced from Europe. Open ground, lawns, pastures, waste places and openings in woods throughout the state.

Poa compressa L. Canada bluegrass

Culms solitary or few together, often gregarious, strongly flattened, wiry, decumbent at base, bluish green, 15-70 cm tall; blades mostly short, 1-4 mm wide; panicle narrow, 3-10 cm long, the usually short branches in pairs, spikelet-bearing to the base; spikelets crowded, sessile, 3- to 6-flowered, 4-6 mm long; glumes 2-3 mm long; lemmas firm, 2-3 mm long, the web at base scant or wanting, keel and marginal nerves slightly pubescent toward base, intermediate nerves obscure. Introduced from Europe. Open ground, open woods, meadows and waste places throughout the state.

Poa arachnifera Torr. Texas bluegrass.

Plants dioecious; culms tufted, 30-75 cm tall; blades mostly 2-4 mm wide, scabrous above; panicle narrow, compact, more or less lobed or interrupted, 5-12 cm long; spikelets mostly 5- to 10-flowered, the pistillate conspicuously cobwebby, the lemmas 5-6 mm long, acuminate, copiously long webby at base, the strongly compressed keel and lateral nerves ciliate-fringed along lower half; staminate lemmas glabrous or with a scant web at base. In fields and pastures. Infrequent in Virginia.

Poa pratensis L. Kentucky bluegrass.

Culms tufted, erect, slightly compressed, 30-100 cm tall; sheaths somewhat keeled; ligule about 2 mm long; blades soft, flat or folded, mostly 2-4 mm wide, the basal often elongated; panicle pyramidal or oblong-pyramidal, open, the lowermost branches usually in a whorl of 5, ascending or spreading, naked below, normally 1 central long one, 2 shorter lateral ones and 3 short intermediate ones; spikelets crowded, 3- to 5-flowered, 3-6 mm long; lemmas copiously webbed at base, silky pubescent on lower half or two-thirds of keel and marginal nerves, intermediate nerves distinct, glabrous. Open woods, meadows and open grounds throughout the state.

Poa cuspidata Nutt. Short-leaved bluegrass. Early bluegrass.

Culms in large lax tufts, 30-50 cm tall, scarcely longer than the basal blades; blades lax, 2-3 mm wide, abruptly cuspidate-pointed; panicle 7-12 cm long, open, the branches mostly in pairs, distant, spreading, spikelet-bearing near ends; spikelets 3- or 4-flowered; lemmas 4-6 mm long, tapering to an acute apex, webbed at base, sparingly pubescent on keel and marginal nerves, intermediate nerves glabrous, distinct. Rocky woods, woodland trails and borders throughout the state. Our earliest flowering native grass.

Poa autumnalis Muhl. ex Ell. No common name known.

Culms in rather large lax tufts, 30-60 cm tall; blades 2-3 mm wide, numerous at base; panicle 10-20 cm long, about as broad, very open, the capillary flexuous branches spreading, bearing a few spikelets near the ends; spikelets 4- to 6-flowered, about 6 mm long; lemmas oblong, obtusely rounded at the scarious-compressed apex, villose on the keel and marginal nerves, pubescent on the internerves below or sometimes nearly to apex. Moist woods mostly in eastern half of the state.

Poa trivialis L. Rough bluegrass. Rough stalked bluegrass.

Culms erect from a decumbent base, often rather lax, scabrous below panicle, 30-100 cm tall; sheaths retrorsely scabrous or scaberulous, at least toward summit; ligule 4-6 mm long; blades scabrous, 2-4 mm wide; panicle oblong, 6-15 mm long, the lower branches about 5 in a whorl; spikelets usually 2- or 3-flowered, about 3 mm long; lemma 2.5-3 mm long, glabrous except the slightly pubescent keel or lateral nerves rarely pubescent, the web at base conspicuous, the nerves prominent. Introduced from Europe. Moist places scattered throughout the state.

Poa alsodes A. Gray. No common name known.

Culms in lax tufts, 30-60 cm tall; blades thin, lax, 2-5 mm wide; panicle 10-20 cm long, very open, the slender branches in distant whorls of threes to fives, finally widely spreading, naked below, few-flowered; spikelets 2- or 3-flowered, about 5 mm long; lemmas gradually acute, webbed at base, pubescent on lower part of keel, otherwise glabrous, faintly nerved. Rich or moist woods. Alleghany Highlands.

Poa languida Hitchc. No common name known.

Culms weak, in loose tufts, 30-60 or even 100 cm tall; ligule about 1 mm long; blades lax, 2-4 mm wide; panicle nodding, 5-10 cm long, the few slender branches mostly in twos or threes, ascending, few-flowered toward the ends; spikelets 2- to 4-flowered, 3-4 mm long; lemmas 2-3 mm long, glabrous except the webbed base, oblong, rather obtuse, firm at maturity. Dry or rocky woods. Rockingham County.

Poa saltuensis Fern. & Wieg. No common name known.

Resembling *P. languida*; differing in the thinner, acute, somewhat longer lemmas. Woodland thickets, Rockbridge and Augusta Counties.

Poa sylvestris A. Gray. Sylvan bluegrass.

Culms tufted, erect, 30-100 cm tall; sheaths glabrous or rarely pubescent, the lower usually antrorsely scabrous; ligule about 1 mm long; blades lax, 2-6 mm wide; panicle erect, 10-20 cm long, much longer than wide, the slender flexuous branches spreading, usually 3 to 6 at a node, the lower usually reflexed; spikelets 2- to 4-flowered, 3-4 mm long; lemmas 2.5-3 mm long, webbed at base, pubescent on internerves. Rich, moist or rocky woods scattered throughout the state.

Poa wolfii Scribn. No common name known.

Culms tufted, erect, 40-80 cm tall; sheaths slightly scabrous; blades crowded toward base of culms, mostly 1-2 mm wide; panicle drooping, 8-15 cm long, the branches ascending, bearing a few spikelets toward the end, the lower mostly in pairs; spikelets 2- to 4-flowered, 5-6 mm long; lemmas 3.5-4.5 mm long, acute, webbed at base, pubescent on keel and marginal nerves, intermediate nerves distinct. Moist woods, Clark County.

Poa bulbosa L. Bulbous bluegrass.

Culms densely tufted, more or less bulbous at base, 30-60 cm tall; blades flat or loosely involute, 1-2 mm wide; panicle ovoid, mostly 5-8 cm long, somewhat contracted, the branches ascending or appressed, some floriferous to base; spikelets mostly proliferous, the florets converted into bulblets with a dark purple base, the bracts extending into slender green tips 5-15 mm long; unaltered spikelets about 5-flowered, apparently not perfecting seeds; lemmas 2.5 mm long, webbed at base, densely silky on keel and marginal nerves, intermediate nerves faint. Introduced from Europe. Fields and meadows, Arlington, Albermarle, Charlotte, Dinwiddie Counties and City of Chesapeake.

Poa nemoralis L. Wood bluegrass.

Culms tufted, 30-70 cm tall; ligule very short; blades rather lax about 2 mm wide; panicle 4-10 cm long, the branches spreading; spikelets 2- to 5-flowered, 3-5 mm long; glumes narrow, sharply acuminate, about as long as first floret; lemmas 2-3 mm long, sparsely webbed at base, pubescent on keel and marginal nerves, intermediate nerves obscure. Occasional in meadows, Arlington and Sussex Counties.

Poa palustris L. Fowl bluegrass.

Culms loosely tufted, glabrous, decumbent at flattened purplish base, 30-150 cm tall; sheaths keeled, sometimes scaberulous; ligule 3-5 mm long or only 1 mm long on innovations; blades 1-2 mm wide; panicle pyramidal or oblong, nodding, yellowish green or purplish, 10-30 cm long, the branches in rather distant fascicles, naked below; spikelets 2- to 4-flowered, about 4 mm long; glumes lanceolate, acute, shorter than first floret; lemmas 2.5-3 mm long, usually bronzed at tip, webbed at base, villose on keel and marginal nerves. Meadows and moist open ground, Bath, Roanoke, Prince William, Arlington, Fauquier, Montgomery Counties.

Polypogon Desf.

Usually decumbent annuals or perennials with flat scabrous blades and dense, bristly, spikelike panicles; spikelets 1-flowered, pedicel disarticulating a short distance below glumes, leaving a short-pointed callus attached; glumes equal, entire or 2-lobed, awned from tip or from between lobes, awn slender, straight; lemma much shorter than glumes, hyaline, usually bearing a slender straight awn shorter than those of the glumes.

1. Glumes slightly lobed, lobes not ciliate *P. monspeliensis*
- 1'. Glumes prominently lobed, lobes ciliate-fringed *P. maritimus*

Polypogon monspeliensis (L.) Desf. Rabbitfoot grass.

Annual; culms erect or decumbent at base, 15-50 cm tall; ligule 5-6 mm long; blades in average plants 4-6 mm wide; panicle dense, spikelike, 2-15 cm long, 1-2 cm wide, tawny yellow when mature; glumes hispidulous, about 2 mm long, awns 6-8 mm long; lemma smooth and shining, about half as long as glumes, the delicate awn exceeding them. Introduced from Europe. Ballast and waste places, Coastal Plain.

Polypogon maritimus Willd. No common name known.

Annual; culms 20-30 cm tall, upright or spreading; ligule as much as 6 mm long; blades usually less than 5 cm long, 2-4 mm wide; panicle mostly smaller and less dense than in *P. monspeliensis*; glumes about 2.5 mm long, hispidulous below, the deep lobes ciliate-fringed, awns 7-10 mm long, lemma awnless. Introduced from Mediterranean region. City of Virginia Beach.

Puccinellia Parl. Alkali-grass.

Low pale smooth tufted annuals or perennials with narrow to open panicles; spikelets several-flowered, usually terete or subterete, the rachilla disarticulating above glumes and between florets; glumes unequal, shorter than first lemmas, obtuse or acute, rather firm, often scarious at tip, the first 1-nerved or sometimes 3-nerved; lemmas usually firm, rounded on back, obtuse or acute, rarely acuminate, usually scarious and often erose at tip, glabrous or puberulent toward base, rarely pubescent on nerves, 5-nerved, nerves parallel, indistinct, rarely rather prominent; palea about as long as lemma or somewhat shorter.

Puccinellia fasciculata (Torr.) Bicknell. No common name known.

Apparently perennial; culms rather stout, 20-50 cm tall, sometimes taller; blades flat, folded or subinvolute, 2-4 mm wide; panicle ellipsoid, 5-15 cm long, the branches fascicled, rather stiffly ascending, some naked at base but with short basal branchlets, all rather densely flowered; spikelets 2- to 5-flowered, 3-4 mm long; glumes ovate, 1 and 1.5 mm long; lemmas 2-2.5 mm long, firm, obtuse. Salt marshes, Accomack County.

See also *Glyceria pallida* which, according to Clausen (1952), belongs in *Puccinellia*.

Sacciolepis Nash.

Annuals or perennials, usually branching, the inflorescence a dense, usually elongate, spikelike panicle; spikelets oblong-conic; first glume much shorter than spikelet; second glume broad, inflated-saccate, strongly many-nerved; sterile lemma narrower, flat, fewer nerved, its palea nearly as long, often subtending a staminate flower; fertile lemma stipitate, elliptic, chartaceous-indurate, the margins inrolled, the palea not enclosed at summit.

Sacciolepis striata (L.) Nash. American cupscale.

Perennial, glabrous, often decumbent and rooting at base; culms as much as 1-2 m tall; sheaths glabrous to more or less papillose-hirsute; blades lanceolate, 4-20 cm long; spikelets about 4 mm long. Marshes, ditches and wet places, Coastal Plain.

Schizachne Hack.

Rather tall perennial with simple culms and open, rather few-flowered panicle; spikelets several-flowered, disarticulating above glumes and between florets, rachilla glabrous; glumes unequal, 3- and 5-nerved; lemmas lanceolate, strongly 7-nerved, long-pilose on callus, awned from just below teeth of prominently bifid apex; palea with softly pubescent, thickened submarginal keels, the hairs longer toward the summit.

Schizachne purpurascens (Torr.) Swallen. False melic.

Culms erect from a loosely tufted decumbent base, 50-100 cm tall; sheaths closed; blades flat, narrowed at base, 1-5 mm wide; panicle about 10 cm long, the branches single or in pairs, more or less drooping, bearing 1 or 2 spikelets; spikelets 2-2.5 cm long; glumes purplish, less than half as long as spikelet; lemmas about 1 cm long, the awn as long as lemma or longer. Rocky woods, Highland County.

Setaria Beauv.

Annual or perennial with narrow terminal panicles, these dense and spikelike or somewhat loose and open; spikelets subtended by one to several bristles, falling free from bristles, awnless; first glume broad, usually less than half the length of the spikelet, 3- to 5-nerved; second glume and sterile lemma equal, or the glume shorter, several-nerved; fertile lemma coriaceous-indurate, transversely rugose or smooth.

1. Bristles below each spikelet numerous, at least more than 5; panicle dense, cylindric, spikelike 2
- 1'. Bristles below each spikelet 1 to 3, or, by the abortion of the spikelets, 4 or 6; panicles not as above 3
2. Plants annual; spikelets 3 mm long; lower floret staminate, palea well developed *S. lutescens*
- 2'. Plants perennial; spikelets 2-2.5 mm long; lower floret neuter, palea reduced *S. geniculata*

3. Bristles more or less retrorsely scabrous *S. verticillata*
 - 3'. Bristles antrorsely scabrous only 4
 4. Culms as much as 3 m tall; bristles 1-2 cm long; fertile
lemma smooth or nearly so *S. magna*
 - 4'. Culms mostly less than 1 m tall 5
 5. Panicle cylindric, tapering above, green; spikelets
falling entire 6
 - 5'. Panicle lobed or interrupted, often large and heavy,
purple or yellow; fruit deciduous from glumes and
sterile lemma *S. italica*
 6. Spikelets 2-2.5 mm long; bristles 1 to 3 below each
spikelet; panicle erect or somewhat nodding *S. viridis*
 - 6'. Spikelets 2.8-3 mm long; bristles 3 to 6 below each
spikelet; panicle conspicuously nodding *S. faberi*
- Setaria lutescens* (Weigel) Hubb. (= *S. glauca* (L.) Beauv.) Yellow foxtail.
Yellow millet. Yellow bristlegrass. Foxtail.

Annual, branching at base; culms erect to prostrate, mostly 50-100 cm tall, compressed; sheaths keeled; blades as much as 25 cm long and 1 cm wide, flat, twisted in a loose spiral, villose toward the base above; panicle dense, evenly cylindric, spike-like, yellow at maturity, mostly 5-10 cm long, about 1 cm thick, the axis densely pubescent; bristles 5 to 20 in a cluster, the longer 2 to 3 times as long as the spikelet; spikelets 3 mm long; fruit strongly rugose. A weed in cultivated soil and waste places throughout the state.

Setaria geniculata (Lam.) Beauv. Knotroot bristlegrass. Knotroot foxtail.

Resembling *S. lutescens* but perennial, producing short knotty branching rhizomes as much as 4 cm long; base of plant slender, wiry; blades mainly straight (not twisted as in *S. lutescens*); bristles yellow or purple, 1 to 3 times or even 6 times as long as the spikelet; spikelets 2-2.5 or even 3 mm long. Open ground, pastures, cultivated soil, salt marshes and moist ground. Mostly eastern half of the state.

Setaria verticillata (L.) Beauv. Bur bristlegrass. Bristly foxtail.

Annual, culm often much branched at base and geniculate-spreading, as much as 1 m long; blades flat, rather thin, scabrous and often more or less pilose, 10-20 cm long, 5-10 mm wide; panicle erect but not stiff, cylindric or somewhat tapering upward, more or less lobed or interrupted, especially toward base, 5-15 cm long, 7-15 mm wide; bristles single below each spikelet, 1 to 3 times as long as the spikelet, retrorsely scabrous; spikelets 2 mm long; fruit finely rugose. Cultivated soil and waste places in coastal swamps.

Setaria magna Griseb. Giant foxtail. Giant bristlegrass.

Annual, robust, erect; culms sparingly branching, as much as 4 m tall and 2 cm thick at base; blades flat, scabrous, as much as 50 cm long and 3.5 cm wide; panicles densely flowered, nodding, often interrupted at base, tapering at each end, as much as 50 cm long and 3 cm thick, those of the branches much smaller; bristles 1-2 cm long; spikelets about 2 mm long; fruit smooth or nearly so, brown and shining at maturity. Marshes and wet places along the coast.

Setaria viridis (L.) Beauv. Green foxtail. Green bristlegrass.

Annual, branching at base, sometimes geniculate-spreading, 20-40 cm tall or even 1 m; blades flat, usually less than 15 cm long and 1 cm wide; panicle erect or

somewhat nodding, densely flowered, green or purple, cylindric, but tapering a little at the summit, usually less than 10 cm long; bristles 1 to 3 below each spikelet, mostly 3 to 4 times their length; spikelets 2-2.5 mm long; fruit very finely rugose. Introduced from Europe. A weed in cultivated soil and waste places scattered throughout the state.

Setaria italica (L.) Beauv. Italian millet. Foxtail millet. German millet. Hungarian millet. Foxtail.

Cultivated form of *S. viridis*, more robust, with broader blades and larger lobed panicles, the fruit smooth or nearly so, shining at maturity, falling away from the remainder of the spikelets. In the larger forms the culms may be as much as 1 cm thick and the panicles as much as 30 cm long and 3 cm thick, yellow or purple, bristles from scarcely longer than the spikelets to 3 to 4 times as long; fruit tawny to red, brown or black. Adventive from East Indies. Cultivated and occasionally an escape. Scattered throughout state.

Setaria faberi Herrm. Giant foxtail. Faber's foxtail.

Similar to *S. viridis*, usually taller; blades softly pubescent to glabrescent; panicle conspicuously nodding; spikelets about 3 mm long, the second glume shorter than the more rugose fruit. Introduced from China. Becoming a weed in waste and cultivated ground. Scattered throughout state.

Sorghastrum Nash.

Perennial erect, rather tall grasses, with auricled sheaths, narrow flat blades, and narrow terminal panicles of 1- to few-jointed racemes; spikelets in pairs, one nearly terete, sessile and perfect, the other wanting, only the hairy pedicel present; glumes coriaceous, brown or yellowish, the first hirsute, the edges inflexed over the second; sterile and fertile lemmas thin and hyaline, the latter extending into a usually well-developed bent and twisted awn.

1. Awn usually 15 mm long or less, once geniculate *S. nutans*

1'. Awn 20-35 mm long, twice geniculate, twisted below
second bend *S. elliottii*

Sorghastrum nutans (L.) Nash. Indian grass. Indian woodgrass.

Culms 1-2.5 m tall from short, scaly rhizomes; blades elongate, flat, mostly 5-10 mm wide, tapering to a narrow base, scabrous; panicle narrow, yellowish, rather dense, 15-30 cm long, contracted and darker at maturity; summit of branchlets, rachis joints and pedicels grayish-hirsute; spikelets 6-8 mm long, lanceolate, hirsute, the awn 1-1.5 cm long, once-geniculate. Open woods and dry slopes throughout the state.

Sorghastrum elliottii (Mohr.) Nash. Elliott's woodgrass.

Culms 1-1.5 m tall, more slender than *S. nutans*, without rhizomes; the base comparatively delicate, smooth or nearly so; blades on the average narrower; panicle loose, 15-30 cm long, nodding at apex, the filiform branchlets and pedicels flexuous but not recurved, with a few long hairs at the tip; spikelets 6-7 mm long, chestnut brown at maturity, with a short blunt bearded callus, the first glume hirsute or glabrescent on the back; awn 2.5-3.5 cm long, twice-geniculate. Open woods, dry hills, and sandy fields in eastern part of state.

Sorghum Moench.

Tall or moderately tall annuals or perennials with flat blades and terminal panicles of 1- to 5-jointed tardily disarticulating racemes; spikelets in pairs, one

sessile and fertile, the other pedicellate, sterile but well developed, usually staminate, the terminal sessile spikelet with two pedicellate spikelets.

Sorghum halepense (L.) Pers. Johnsongrass.

Perennials with culms 50-150 cm tall, from extensively creeping scaly rhizomes; blades mostly less than 2 cm wide; panicle open, 15-50 cm long; sessile spikelet 4.5-5.5 mm long, ovate, appressed-silky, the readily deciduous awn 1-1.5 cm long, geniculate, twisted below; pedicellate spikelet 5-7 mm long, lanceolate. Open ground, fields and waste places throughout the state. Cultivated for forage but becomes a troublesome weed especially for corn farmers since it harbors corn viruses.

Spartina Schreb. Cordgrass.

Erect, often stout tall perennials, with usually extensive creeping, firm, scaly rhizomes, long tough blades and 2 to many appressed or sometimes spreading spikes racemose on the main axis, the slender tips of the rachises naked, often prolonged; spikelets 1-flowered, much flattened laterally, sessile and usually closely imbricate on one side of a continuous rachis, disarticulating below the glumes, the rachilla not exceeding beyond the floret; glumes keeled, 1-nerved, or the second with a second nerve on one side, acute or short-awned, the first shorter than, the second often exceeding, the lemma; lemma firm, keeled, the lateral nerves obscure, narrowed to a rather obtuse point; palea 2-nerved, keeled and flattened, the keel between or at one side of the nerves.

1. Blades usually more than 5 mm wide, flat when fresh, at least at base, tip involute; plants mostly robust and more than 1 m tall 2
- 1'. Blades less than 5 mm wide; involute; plants mostly slender and less than 1 m tall *S. patens*
2. First glume nearly as long as the floret, slender-acuminate, the second with an awn as much as 7 mm long; spikes somewhat distant, mostly more or less spreading *S. pectinata*
- 2'. First glume shorter than the floret, acute, the second acute or mucronate but not slender-awned; spikes approximate, usually appressed 3
3. Blades very scabrous on margins; glumes strongly hispid-scabrous on keels *S. cynosuroides*
- 3'. Blades glabrous throughout or minutely scabrous on the margins; glumes glabrous or usually softly hispidulous or ciliate on the keels *S. alterniflora*

Spartina patens (Ait.) Muhl. Saltmeadow cordgrass.

Culms slender, mostly less than 1 m tall with long slender rhizomes; blades sometimes flat but mostly involute, less than 3 mm wide; spikes 2 to several, appressed to somewhat spreading, 2-5 cm long, rather remote on axis; spikelets 8-12 mm long; first glume about half as long as the floret, the second longer than the lemma; lemma 5-7 mm long, emarginate at apex; palea a little longer than lemma. Salt marshes and sandy meadows along the coast.

Spartina pectinata Link. Prairie cordgrass. Freshwater cordgrass.

Culms 1-2 m tall, firm or wiry; blades elongate, flat when fresh, soon involute in drying, as much as 1.5 cm wide, very scabrous on the margins; spikes mostly 10 to

20, sometimes fewer or as many as 30, mostly 4-8 cm long, ascending, sometimes appressed, rarely spreading, on rather slender peduncles; glumes hispid-scabrous on keel, the first acuminate or short-awned, nearly as long as the floret, the second exceeding the floret, tapering into an awn as much as 7 mm long; lemma glabrous except the scabrous keel, 7-9 mm long, apex with 2 rounded teeth; palea usually a little longer than lemma. Fresh-water marshes extending into brackish marshes along the coast. Sparse throughout state.

Spartina cynosuroides (L.) Roth. Big cordgrass. Salt reedgrass.

Culms 1-3 m tall, stout, the base sometimes as much as 2 cm thick; blades flat, 1-2.5 cm wide, very scabrous on the margins; spikes numerous, ascending, approximate, often dark-colored, usually more or less peduncled, mostly 3-8 cm long; spikelets about 12 mm long; glumes acute, hispid-scabrous on keel, the first much shorter than floret, the second longer than floret, sometimes rather long-acuminate; lemma not toothed at apex; palea a little longer than lemma. Salt or brackish marshes along coast and margins of tidal streams.

Spartina alterniflora Loisel. Salt-marsh cordgrass. Smooth cordgrass. Salt water cordgrass.

Culms soft and spongy or succulent at base, often 1 cm or more thick, smooth throughout or the margins of the blades minutely scabrous, 0.5-2.5 m tall; blades flat, tapering to a long involute tip, 0.5-1.5 cm wide; spikes appressed, 5-15 cm long; spikelets somewhat remote, barely overlapping or sometimes more imbricate, mostly 10-11 mm long; glumes glabrous or hispid on the keel, the first acute, narrow, shorter than the lemma, the second obtusish, a little longer than the lemma; floret sparingly pilose or glabrous. Salt marshes along the coast, often growing in water.

Sphenopholis Scribn. Wedgegrass.

Slender perennials (rarely annual) with usually flat blades and narrow shining panicles; spikelets 2- or 3-flowered, the pedicel disarticulating below glumes, the rachilla produced beyond the upper floret as a slender bristle; glumes unlike in shape, the first narrow, usually acute, 1-nerved, the second broadly ovate, 3- to 5-nerved, the nerves sometimes obscure, mostly somewhat coriaceous, the margin scarious; lemmas firm, scarcely nerved, awnless or rarely with an awn from just below the apex, the first a little shorter or a little longer than the second glume; palea hyaline, exposed.

- 1. Panicle dense, usually spikelike, erect or nearly so *S. obtusata*
 - 1'. Panicle not dense, lax, nodding, not spikelike 2
 - 2. Spikelets awned *S. pallens*
 - 2'. Spikelets awnless (rarely awned in *S. filiformis*) 3
 - 3. Lemmas glabrous; second glume acute or subacute;
panicle many-flowered *S. intermedia*
 - 3'. Lemmas scabrous; second glume broadly rounded
at summit; panicle relatively few flowered 4
 - 4. Blades rarely more than 10 cm long, flat, 2-5 mm wide . . . *S nitida*
 - 4'. Blades elongate, flat to subinvolute, mostly less
than 2 mm wide *S. filiformis*
- Sphenopholis obtusata* (Michx.) Scribn. Prairie wedgegrass. Prairie wedge-scale.

Culms erect, tufted, 30-100 cm tall; sheaths glabrous to finely retrorsely pubescent; blades flat, glabrous, scabrous, or pubescent, mostly 2-5 mm wide; panicle erect or nearly so, dense, spikelike to interrupted or lobed, rarely slightly looser, 5-20 cm long; spikelets 2.5-3.5 mm long, the two florets closer together than in the other species; second glume very broad, subcucullate, somewhat inflated at maturity, 5-nerved, scabrous; lemmas minutely papillose, rarely mucronate or with a short straight awn, the first about 2.5 mm long. Open woods, old fields, moist ground throughout the state.

Sphenopholis pallens (Bieler) Scribn. No common name known.

Culms erect, about 60 cm tall; lower sheaths minutely pubescent, the upper glabrous; blades flat, glabrous, 1-2 mm wide; panicle narrow, nodding, loose or somewhat compact, 15-25 cm long, the branches ascending, the lower distant; spikelets 2- or 3-flowered, 3-3.5 mm long; second floret scaberulous, usually awned just below the apex, the awn scabrous, geniculate, 1-2 mm long. Rich wooded slopes in Coastal Plain.

Sphenopholis intermedia (Rydb.) Rydb. Slender wedgegrass.

Culms erect in small tufts, 30-120 cm tall; sheaths glabrous or pubescent, blades flat, often elongate, lax, mostly 2-6 mm wide, sometimes wider, mostly scaberulous, occasionally sparsely pilose; panicle nodding, dense to open, mostly 10-20 cm long, the branchlets spikelet-bearing from base; spikelets 3-4 mm long; second glume relatively thin, acute or subacute, about 2.5 mm long; lemmas subacute, rarely mucronate, smooth or rarely minutely roughened, mostly 2.5-3 mm long. Damp or rocky woods, slopes and moist places. Coastal Plain, Fall Belt and Piedmont.

Sphenopholis nitida (Bieler) Scribn. No common name known.

Culms tufted, leafy at base, slender, shining, 30-70 cm tall; sheaths and blades mostly softly pubescent, occasionally glabrous, the blades 2-5 mm wide, 3-10 cm long, the basal sometimes longer; panicle rather few-flowered, mostly 8-12 cm long, the filiform branches distant, ascending, spreading in anthesis; spikelets 3-3.5 mm long; glumes about equal in length, usually nearly as long as the first floret, the first glume broader than in the other species, the second broadly rounded at summit, at least the second lemma scabrous-papillose. Dry or rocky woods throughout the state.

Sphenopholis filiformis (Chapm.) Scribn. No common name known.

Culms erect, very slender, 30-60 cm tall; blades lax, flat to subinvolute, mostly less than 2 mm wide; panicle slender, often nodding, 5-15 cm long, the short branches rather distant, erect or ascending; spikelets 3-4 mm long, the 2 florets rather distant; second glume broadly rounded at summit, about 2 mm long; lemmas obtuse to subacute, rarely with a short spreading awn, the first smooth, the second minutely roughened. Dry soil, Coastal Plain.

Sporobolus R. Br. Dropseed.

Annuals or perennials with small spikelets in open or contracted panicles; spikelets 1-flowered, the rachilla disarticulating above the glumes; glumes 1-nerved, usually unequal, the second often as long as the spikelet; lemma membranaceous, 1-nerved, awnless; palea usually prominent and as long as the lemma or longer; caryopsis free from the lemma and palea, falling readily from the spikelet at maturity, the pericarp free from the seed, usually thin and closely enveloping it, but readily slipping away when moist.

1. Plants annual 2
 - 1'. Plants perennial 3
 2. Lemma pubescent *S. vaginiflorus*
 - 2'. Lemma glabrous *S. neglectus*
 3. Plants with creeping rhizomes, panicle narrow or
spikelike *S. virginicus*
 - 3'. Plants without creeping rhizomes 4
 4. Glumes nearly equal, much shorter than lemma 5
 - 4'. Glumes unequal or, if equal, as long as the spikelet 6
 5. Panicle branches short and appressed, panicle spikelike . . . *S. poiretii*
 - 5'. Panicle branches slender, ascending, the panicle scarcely
spikelike *S. indicus*
 6. Spikelets mostly 3-7 mm long; plants usually
less than 1 m tall 7
 - 6'. Spikelets 1-2.5 mm long *S. cryptandrus*
 7. Second glume shorter than lemma; panicle contracted,
more or less included in sheath 8
 - 7'. Second glume about as long as lemma; panicle open,
not included *S. junceus*
 8. Lemma glabrous, palea not exceeding it *S. asper*
 - 8'. Lemma pubescent, the acuminate palea exceeding it *S. clandestinus*
- Sporobolus vaginiflorus* (Torr.) Wood. Poverty dropseed. Dropseed.

Annual, spreading from base; culms erect to spreading, mostly 20-40 cm tall, sometimes as much as 75 cm; blades slender, subinvolute, the lower elongate; panicles terminal and axillary, slender mostly not more than 3 cm long, the terminal exserted or partly included, the axillary included in the sheath or slightly exserted, late in the season the sheaths swollen and containing cleistogamous spikelets; glumes acute, about equal, 3-5 mm long; lemma as long as glumes or exceeding them, acute or acuminate, rather sparsely pubescent, sometimes mottled with dark spots; palea acuminate, sometimes longer than lemma. Sandy soil or open waste ground, scattered throughout the state.

Sporobolus neglectus Nash. Annual dropseed.

Differing from *S. vaginiflorus* chiefly in the smaller, paler, plumper spikelets, 2-3 mm long, and in the glabrous lemma; lower blades often sparsely pilose; panicles usually entirely hidden in the more swollen sheaths. Dry open ground and sandy fields in Alleghany Highlands and Valleys.

Sporobolus virginicus (L.) Kunth. Virginia dropseed.

Perennial with numerous branching widely creeping slender rhizomes (yellowish in drying); culms erect, 10-40 cm tall; sheaths overlapping, more or less pilose at the throat; blades flat or becoming involute especially toward the fine point, conspicuously distichous, mostly less than 5 cm long or on the innovations longer; panicle pale, contracted or spikelike, 2-8 cm long, 5-10 mm thick; spikelets 2-2.5 mm long; glumes and lemma about equal. Sandy or muddy seashores and saline marshes, forming extensive colonies with relatively few flowering culms, Coastal Plain.

Sporobolus poiretii (Roem. & Schult.) Hitchc. Smutgrass.

Perennial; culms erect, solitary or in small tufts, 30-100 cm tall; blades flat or involute, rather firm, 2-5 mm wide at base, elongate, tapering to a fine point; panicle usually spikelike but more or less interrupted, 10-40 cm long, the branches appressed or ascending; spikelets about 2 mm long; glumes obtuse, some what unequal, about half as long as spikelet or less; lemma acutish. Open ground, waste places and roadsides scattered throughout the state. Panicle sometimes covered with a black fungus, which suggests the common name.

Sporobolus cryptandrus (Torr.) A. Gray. Sand dropseed.

Perennial, usually in rather small tufts; culms erect or spreading, sometimes prostrate, 30-100 cm tall; sheaths with a conspicuous tuft of long white hairs at summit; blades flat, 2-5 mm wide, more or less involute in drying, tapering to a fine point; panicles terminal and axillary, usually included at the base, sometimes entirely included, the well-developed terminal panicles open, as much as 25 cm long, the branches spreading or sometimes reflexed, rather distant, naked at base, as much as 8 cm long or even more, the spikelets crowded along the upper part of the main branches; spikelets from pale to leaden, 2-2.5 mm long; first glume one-third to half as long, the second about half as long as the acute lemma and palea. Sandy open ground, Piedmont and Coastal Plain.

Sporobolus indicus (L.) R. Br. Smutgrass. Rattail smutgrass.

Resembling *S. poiretii* but the blades more slender, especially at base, and the panicle blades longer, more slender, less densely flowered, loosely ascending to somewhat spreading; the panicle not spikelike. Coastal Plain and across southern part of state. The second edition of Hitchcock's Manual and the eighth edition of Gray's Manual places only *S. poiretii* in Virginia. Earlier editions place *S. indicus* in Virginia also. Harvill *et al.* consider *S. poiretii* a synonym of *S. indicus*. See also Riggins, R. 1977. A biosystematic study of the *Sporobolus asper* complex (Gramineae). Iowa St. J. Res. 51:287-321.

Sporobolus junceus (Michx.) Kunth. No common name known.

Perennial, in dense bunches; culms erect, slender, about 3-noded, 30-60 cm tall; blades folded or involute, slender, glabrous; panicle mostly bronze brown, oblong or narrowly pyramidal, open, 7-15 cm long, 2-5 cm wide, the flexuous branches (2-3 cm long) in rather regular whorls 1-3 cm apart, widely spreading to ascending, naked at base, the short-pedicelled spikelets appressed along the upper part; spikelet about 3 mm long; first glume about half as long, the second glume as long as the acute lemma or a little longer. Pine barrens of Coastal Plain.

Sporobolus asper (Michx.) Kunth. No common name known.

Perennial; culms erect, often rather stout, solitary or in small tufts, 60-120 cm tall; blades elongate, flat, becoming involute, 1-4 mm wide at base, tapering to a fine point; panicle terminal and axillary, pale or whitish, sometimes purplish, contracted, more or less spikelike, usually enclosed at base or sometimes entirely in the inflated upper sheath, 5-15 cm long; spikelets 4-6 mm long; glumes rather broad, keeled, subacute, the first about half as long as the spikelet, the second two-thirds to three-fourths as long; lemma and palea subequal, glabrous, the tip boat-shaped. Prairies and sandy meadows, Coastal Plain, Alleghanies and Valleys.

Sporobolus clandestinus (Bieler) Hitchc. No common name known.

Perennial; culms relatively stout to slender, erect to spreading, 50-100 cm tall; lower sheaths sometimes pilose; blades flat, becoming involute, with a long fine

point; panicle narrow, contracted, 5-10 cm long, usually partly enclosed; spikelets 5-7 mm long, the glumes keeled, acute or subacute, the first more than half as long as the spikelet, the second longer than the first; lemma sparsely appressed-pubescent, acuminate, the palea longer, sometimes as much as 10 mm long. Sandy fields, pine barrens and hills, Coastal Plain and scattered in rest of state.

Stipa L. Needlegrass.

Tufted perennials, with usually convolute blades and mostly narrow panicles; spikelets 1-flowered, disarticulating above the glumes, the articulation oblique, leaving a bearded, sharp-pointed callus attached to the base of the floret; glumes membranaceous, often papery, acute, acuminate, or even aristate, usually long and narrow; lemma narrow, terete, firm or indurate, strongly convolute, rarely the margins only meeting, terminating in a prominent awn, the junction of body and awn evident, the awn twisted below, geniculate, usually persistent; palea enclosed in the convolute lemma.

Stipa avenacea L. Blackseed needlegrass. Black oatgrass.

Culms 60-100 cm tall; ligule about 3 mm long, blades 20-30 cm long, 1 mm wide, flat or involute; panicle 10-15 cm long, open, the slender branches 2-4 cm long, bearing 1 or 2 spikelets; glumes 1.5 cm long; lemma dark brown, 9-10 mm long, the callus 2 mm long, the body glabrous, papillose-roughened toward the summit, awn scabrous, 4.5-6 cm long, twice-geniculate. Dry or rocky open woods throughout the state.

Tridens Roem. & Schult.

Erect, tufted perennials, rarely rhizomatous or stoloniferous, the blades usually flat, the inflorescence an open to contracted or capitate panicle; spikelets several-flowered, the rachilla disarticulating above the glumes and between the florets; glumes membranaceous, often thin, nearly equal in length, the first sometimes narrower, 1-nerved, the second rarely 3- to 5-nerved, acute to acuminate; lemmas broad, rounded on the back, the apex from minutely emarginate or toothed to deeply and obtusely 2-lobed, 3-nerved, the lateral nerves sometimes conspicuously so throughout; palea broad, the 2 nerves near the margin sometimes villose; grain concavo-convex. (*Triodia* in Blomquist, 1948).

1. Panicle open or loose, not dense or spikelike 2
- 1'. Panicle narrow, contracted or spikelike, the branches
appressed *T. strictus*
2. Panicle erect, the branches stiffly spreading; pulvini
extending entirely around the base of the branches *T. chapmani*
- 2'. Panicle drooping; pulvini confined to the upper
surface at the base of the branches *T. flavus*

Tridens strictus (Nutt.) Nash. No common name known.

Culms rather stout, erect, 1-1.5 m tall; blades elongate, flat or loosely involute, 3-8 mm wide; panicle dense, spikelike, more or less interrupted below, narrowed above, 10-30 cm long; spikelets short-pedicelled, 4- to 6-flowered, about 5 mm long, the florets closely imbricate; glumes as long as the spikelet, or nearly so, the apex spreading, the keel glandular-viscid toward maturity; lemmas about 3 mm long, obtuse, the keel and margins pilose on the lower half to two-thirds, the midnerve excurrent as a minute awn; palea about as long as the lemma, short-ciliate on the

sharp keels, not strongly bowed out. Low moist grounds and low woods, Coastal Plain. Not common.

Tridens chapmani (Small) Chase. No common name known.

Culms 60-100 cm tall, slender or occasionally rather coarse; lower leaves crowded toward the base, the sheaths narrow, spreading from the culm, keeled, glabrous, densely villose on the collar; blades flat or loosely rolled, elongate, alternate, 3-7 mm wide, narrowed toward the base; panicles 15-25 cm long, usually erect, the branches and branchlets stiffly spreading, the bases of the principal ones surrounded by glandular hairy pulvini; spikelets long-pedicelated, divergent, 7-10 mm long, pale or purple-tinged. Dry pine and oak woods of Coastal Plain.

Tridens flavus (L.) Hitchc. Purple top. Fall red top. Grease grass

Culms erect, tufted, 1-1.5 m tall, basal sheaths compressed-keeled, blades elongate, 3-10 mm wide, very smooth; panicle open, 15-35 cm long, usually purple or finally nearly black, rarely yellowish, the branches distant, spreading to drooping, naked below, as much as 15 cm long, with slender divergent branchlets, the axils pubescent, the axis, branches, branchlets and pedicels viscid; spikelets oblong, mostly 6- to 8-flowered, 5-8 mm long; glumes subacute, mucronate; lemmas 4 mm long, obtuse, pubescent on the callus and lower half of the keel and margins, the 3 nerves excurrent; palea a little shorter than the lemma, somewhat bowed out below. Old fields and open woods throughout the state.

Triplasis Beauv.

Slender tufted annuals or perennials, with short blades, short open, few-flowered, purple, terminal panicles and cleistogamous narrow panicles in the axils of the leaves; spikelets few-flowered, V-shaped, the florets remote, the rachilla slender, disarticulating above the glumes and between the florets; glumes nearly equal, smooth, 1-nerved, acute; lemmas narrow, 3-nerved, 2-lobed, the nerves parallel, silky-villose, the lateral pair near the margin, the mid-nerve excurrent as an awn, as long as the lobes or longer, palea shorter than the lemma, the keels densely long-villose on the upper half.

Triplasis purpurea (Walt.) Chapm. Purple sandgrass.

Annual, often purple; culms ascending to widely spreading, pubescent at the several to many nodes, 30-100 cm tall, rarely taller; blades flat or loosely involute, 1-3 mm wide, mostly 4-8 cm long; panicle 3-5 cm long, with few spreading few-flowered branches, the axillary more or less enclosed in the sheaths; spikelets short-pedicelated, 2- to 4-flowered, 6-8 mm long; lemmas 3-4 mm long, the lobes broad, rounded or truncate, the nerves and callus densely short-villose, the awn about as long as the lobes or somewhat exceeding them; palea conspicuously silky-villose on the upper half of the keels; grain about 2 mm long. Dry sandy soil of Coastal Plain.

Tripsacum L. Gamagrass.

Robust perennials, with usually broad flat blades and monoecious terminal and axillary inflorescences of 1 to 3 racemes, the pistillate part below, breaking up into bony, seedlike joints, the staminate above on the same rachis, deciduous as a whole; spikelets unisexual; staminate spikelets 2-flowered, in pairs on one side of a continuous rachis, one sessile, the other sessile or pedicellate, similar to those of *Zea*, the glumes firmer; pistillate spikelets solitary (a minute rudiment of a sterile spikelet, sometimes found) on opposite sides at each joint of the thick hard

articulate lower part of the same rachis, sunken in hollows in the joints, consisting of one perfect floret and a sterile lemma; first glume coriaceous, nearly infolding the spikelet, fitting into and closing the hollow of the rachis; second glume similar to the first but smaller, infolding the remainder of the spikelet; sterile lemma, fertile lemma and palea very thin and hyaline, these progressively smaller.

Tripsacum dactyloides (L.) L. Eastern gamagrass.

Plants in large clumps, with thick knotty rhizomes, 2-3 m tall or sometimes taller, glabrous throughout; blades usually 1-2 cm wide, flat, scabrous on the margin; inflorescence 15-25 cm long, the pistillate part one-fourth the entire length or less, the terminal racemes usually 2 or 3, sometimes only 1, those of the branches usually solitary; pistillate spikelets 7-10 mm long, the joints rhombic; staminate spikelets 7-11 mm long, both of a pair nearly sessile, the glumes rather chartaceous. Swales, banks of streams and moist places throughout the eastern and central parts of the state.

Trisetum Pers. *Trisetum*.

Tufted perennials with flat blades and open or usually contracted or spike-like shining panicles; spikelets usually 2-flowered, sometimes 3- to 5-flowered, the rachilla prolonged behind the upper floret, usually villose; glumes somewhat unequal, acute, the second usually longer than the first floret; lemmas usually short-bearded at base, 2-toothed at apex, the teeth often awned, bearing from the back below the cleft apex a straight and included or usually bent and exerted awn.

Trisetum pennsylvanicum (L.) Beauv. ex Roem. and Schult. (= *Sphenopholis pennsylvanica* (L.) Hitchc. in Harvill *et al.*, 1987). No common name known.

Culms slender, weak, usually subgeniculate at base, 50-100 cm tall; sheaths glabrous or rarely scabrous; blades flat, scabrous, 2-5 mm wide; panicle narrow, loose, nodding, 10-20 cm long; pedicels disarticulating about the middle or toward the base; spikelets 5-7 mm long, 2-flowered, the long rachilla internodes slightly hairy; glumes mostly 4-5 mm long, acute, the second wider; lemmas acuminate, the first usually awnless, the second awned below the 2 setaceous teeth, the awn horizontally spreading, 4-5 mm long. Swamps and wet places in Coastal Plain.

Uniola L.

Rather tall, erect perennials, with flat or sometimes convolute blades and narrow or open panicles of compressed, sometimes very broad and flat spikelets; spikelets 3- to many-flowered, the lower 1 to 6 lemmas empty, the rachilla disarticulating above the glumes and between the florets; glumes compressed-keeled, rigid, usually narrow, 3- to 7-nerved, acute or acuminate, rarely mucronate; lemmas compressed, sometimes conspicuously flattened, chartaceous, many-nerved, the nerves sometimes obscure, acute or acuminate, the empty ones at the base and the uppermost usually reduced; palea rigid, strongly keeled, bowed out at the base; stamen 1.

- 1. Rhizomes extensively creeping; blades firm, flat at base, tapering into a long flexuous involute point; empty lemmas about 4; coastal dunes *U. paniculata*
- 1'. Rhizomes wanting or short and knotty; blades thin, flat; empty lemma 1; rich or moist woods 2
- 2. Spikelets 8- to 12-flowered on slender pedicels; panicle nodding or drooping *U. latifolia*

- 2'. Spikelets 3- to 7-flowered, nearly sessile; panicle erect,
nearly simple, branches stiff 3
3. Collar of sheath pubescent, the sheaths commonly loosely
long-pubescent, rarely glabrous *U. sessiliflora*
- 3'. Collar and sheaths glabrous or nearly so *U. laxa*
Uniola paniculata L. Sea oats.

Culms stout, about 1 m tall, from extensively creeping rhizomes; blades flat, firm, elongate, becoming involute toward the long, fine flexuous point; panicle pale, narrow, condensed, heavy and nodding, 20-40 cm long, the branches arching and drooping, as much as 12 cm long; spikelets very flat, 10- to 20-flowered, mostly 2-2.5 cm long, 1 cm wide, the first 4 to 6 lemmas empty, the slender pedicels shorter than the spikelets; lemmas about 9-nerved, strongly compressed-keeled, about 1 cm long, acute; palea acute, as long as the lemma, the strong wings of the keels ciliate. Sand dunes of the sea coast on Eastern Shore, Cities of Hampton, Chesapeake and Virginia Beach.

Uniola latifolia Michx. Broadleaf uniola. Broadleaf sea oats. Inland sea oats.

Culms 1-1.4 m tall, with short strong rhizomes, forming colonies; blades flat, narrowly lanceolate, 10-20 cm long, mostly 1-2 cm wide; panicle open, drooping, 10-20 cm long, the branches bearing a few large, very flat spikelets, the pedicels capillary; spikelets 8- to 12-flowered, 2-3.5 cm long, 1-1.5 cm wide, green or finally tawny, the first lemma empty; lemmas lanceolate, strongly compressed-keeled, acute, about 1 cm long, striate-nerved, the keel ciliate with soft ascending hairs, the callus pilose; palea shorter than the lemma, wing-keeled; anther minute, the flower cleistogamous; caryopsis flat, oval, black, 5 mm long. Rich woods throughout the state.

Uniola sessiliflora Poir. No common name known.

Culms erect, 0.5-1.5 m tall, in loose tufts with short rhizomes; sheaths pilose, at least toward the summit; blades elongate, firm, mostly sparsely pilose on the upper surface toward the base, 5-10 mm wide, tapering to base; panicle long-exserted, 20-50 cm long, narrow, the branches distant, stiffly ascending or appressed, the lower as much as 7 cm long, the upper short, somewhat capitate; spikelets nearly sessile, aggregate in clusters, flat, usually 3- to 5-flowered, broadly V-shaped at maturity, the first lemma empty; glumes about 2 mm long; lemmas spreading, about 5 mm long, acuminate, beaked, especially before maturity, striate-nerved; palea shorter than the lemma, acute, broad, the keels narrowly winged; grain black, 3 mm long, at maturity spreading the lemma and palea; anther 1.3 mm long. Rich woods of Coastal Plain.

Uniola laxa (L.) B.S.P. No common name known.

Culms slender, 60-100 cm tall, erect to nodding from a loosely tufted sometimes knotty base; blades elongate, flat to sometimes loosely involute, 3-6 mm wide; panicle narrow, slender, 15-30 cm long, the branches short, appressed, approximate, the lower sometimes 3 cm long and distant; spikelets nearly sessile, approximate, flat, usually 3- to 4-flowered, the first lemma empty; lemmas spreading, 4-5 mm long, gradually acuminate, striate-nerved; palea broad, the keels narrowly winged; grain black, 2.5 mm long, at maturity spreading the lemma and palea; anther 1.2 mm long. Moist woods of Coastal Plain and Piedmont, occasionally Ridges and Valley.

The last three species, *U. latifolia*, *U. sessiliflora* and *U. laxa*, are placed by Gould and Shaw (1983) in the genus *Chasmanthium*.

Zizania L. Wildrice.

Tall aquatic annuals or perennials, with flat blades and large terminal panicles, the lower branches ascending or spreading, bearing the pendulous staminate spikelets, the upper branches ascending or spreading, at maturity erect, bearing appressed pistillate spikelets, the staminate spikelets early deciduous, the pistillate spikelets tardily deciduous; spikelets unisexual, 1-flowered, disarticulating from the pedicel; glumes obsolete, represented by a small collarlike ridge; pistillate spikelet terete, angled at maturity; lemma chartaceous, 3-nerved, tapering into a long slender awn; palea 2-nerved, closely clasped by the lemma; grain cylindric, 1-2 cm long; staminate spikelet soft; lemma 5-nerved, membranaceous, linear, acuminate or awn-pointed; palea about as long as the lemma, 3-nerved; stamens 6.

Zizania aquatica L. Annual wildrice. Indian rice. Wildrice. Southern wildrice. Broadleaved wildrice.

Annual; culms robust, usually 2-3 m tall; blades elongate, 1-4 cm wide, scaberulous; ligule 10-15 mm long; panicles mostly 30-50 cm long, the branches mostly 15-20 cm long; lemma and palea of pistillate spikelet about 2 cm long, thin, hispid throughout. Marshes and borders of streams and ponds, usually in shallow water in Coastal Plain to Fall Belt.

Zizaniopsis Doell & Aschers.

Robust perennial marsh grasses, with stout creeping rhizomes, broad flat blades and large open panicles; spikelets unisexual, 1-flowered, disarticulating from the pedicel, mixed on the same branches of the panicle, the staminate below; glumes wanting; lemma 7-nerved, short-awned in the pistillate spikelets; palea 3-nerved; staminate spikelets with 6 stamens; styles rather long, united; fruit obovate, free from the lemma and palea, coriaceous, smooth and shining, beaked with the persistent style; seed free from the pericarp.

Zizaniopsis miliacea (Michx.) Doell and Aschers. Southern wildrice. Marsh millet.

Culms 1.3 m tall or even taller; blades glabrous except the very scabrous margins, 1-2 cm wide, the midrib stout; panicle rather narrow, nodding, 30-50 cm long, the numerous branches fascicled, as much as 15-20 cm long, naked at base; spikelets 6-8 mm long, short awned, the staminate slender, the pistillate turgid at maturity. Marshes, creeks and riverbanks, Coastal Plain and Piedmont.

GLOSSARY

Acuminate. Gradually tapering to a sharp point.

Acute. Sharp-pointed.

Anthesis. The period when the lemma and palea are expanded and the anthers and stigma are mature.

Antorse. Directed upwards or forwards.

Apiculate. Having a minute, pointed tip.

Appressed. Lying close against an organ.

Arcuate. Curved like a bow.

Aristate. Awned; provided with a bristle.

Auricle. An ear-like lobe.

Awn. A slender bristle arising from the end or back of a glume or lemma.

Axil. The angle between an organ and the axis to which it is attached.

Axis. The main stem of an inflorescence.

Bifid. Two-cleft or two-lobed.

Blade. The part of a leaf above the sheath.

Bract. Reduced, modified leaf.

Bristle. A stiff, slender appendage.

Bulb. An underground stem with fleshy scales like an onion.

Callus. The hardened base of a mature lemma in some grasses.

Capillary. Very slender, hairlike.

Capitate. In a globular cluster or head.

Caryopsis. The grain or fruit of grasses.

Chartaceous. Having the texture of writing paper.

Ciliate. Fringed with hairs on the margin, like an eyelash.

Cleistogamous. Applied to flowers or florets when fertilized without opening.

Collar. The area on the under side of a leaf at the junction of sheath and blade.

Convolute. Rolled longitudinally.

Coriaceous. Leathery in texture.

Corm. The hard swollen base of a stem.

Cucullate. Having the shape of a hood.

Culm. The jointed stem of a grass.

Deciduous. Falling away; the opposite of persistent.

Decumbent. Curved upward from a horizontal or inclined base.

Depauperate. Impoverished or dwarfed.

Diffuse. Open and much-branched.

Dioecious. Unisexual, the two kinds of flowers on separate plants.

Digitate. Several racemes or spikes arising from the summit of a peduncle.

Distichous. Conspicuously 2-ranked.

Ellipsoid. Shaped nearly like a football.

Excurrent. Running beyond.

Exserted. Protruding.

Fascicle. A little bunch or cluster.

Fertile. Capable of producing fruit.

Fibrillose. Furnished with fibers.

Filiform. Threadlike.

Fimbriate. Fringed.

- Flexuous.** Bent alternately in opposite directions.
- Floret.** The palea and lemma with the included flower.
- Fusiform.** Broadest in the middle, tapering to each end.
- Geniculate.** Bent abruptly.
- Glabrescent.** Tending to become smooth.
- Glabrous.** Without hairs; smooth.
- Gland.** A structure that secretes a fluid.
- Glaucous.** Covered with a bluish waxy coating.
- Glumes.** The two bracts at the base of a spikelet.
- Hirsute.** Bearing straight, stiff hairs.
- Hispid.** Bearing stiff hairs.
- Imbricate.** Overlapping.
- Indurate.** Hard.
- Inflorescence.** The flowering part of a plant.
- Innovation.** The basal shoot of a perennial grass.
- Internode.** The part of a stem between the nodes.
- Involute.** Rolled inward from the edges, the upper surface within.
- Joint.** The node of a culm.
- Keel.** The sharp fold at the back of a sheath, blade or lemma.
- Lanate.** Woolly.
- Lanceolate.** Narrow, tapering to both ends, but the broadest part below the middle.
- Lax.** Loose.
- Lemma.** The lower of the two bracts inclosing the grass flower.
- Ligule.** A thin appendage on the upper side of a leaf at the junction of the sheath and the blade.
- Linear.** Long and narrow.
- Monoecious.** Unisexual with both kinds of flowers on the same plant.
- Mucronate.** Provided with a minute awn or excurrent midnerve of an organ.
- Nerve.** A vein of blades, glumes and lemmas.
- Node.** The joint of a culm.
- Ovate.** Egg-shaped in outline, the broadest part below the middle.
- Palea.** The inner bract of a floret.
- Panicle.** An inflorescence with a main axis and branches.
- Papillose.** Bearing minute, nipple-like projections.
- Pectinate.** Comb-like; spikelets closed together, parallel and branching from the rachis like the teeth of a comb.
- Pedicel.** The stalk of a spikelet.
- Perfect.** Flowers that have both stamens and pistils.
- Pericarp.** The ripened walls of the ovary when it becomes a fruit.
- Persistent.** Remaining attached.
- Pilose.** Bearing soft, straight hairs.
- Pubescent.** Covered with hairs.
- Pulvinus.** The swelling at the base of the branches of some panicles which cause them to spread.
- Raceme.** An unbranched flower cluster bearing pedicelled flowers on an elongated rachis.

- Rachilla.** The axis of a spikelet.
Rachis. The axis of a spike or raceme.
Retrorse. Pointing backward.
Rhizome. A creeping, underground stem.
Rosette. A cluster of radiating basal leaves.
Rudiment. An imperfectly developed organ or part.
Rugose. Wrinkled.
Saccate. Bag or sac-like.
Scabrous. Rough.
Secund. One-sided or arranged along one side.
Sessile. Without a pedicel.
Serrate. Saw-toothed.
Setaceous. Bristle-like.
Sheath. The lower part of a leaf, enclosing the stem.
Spathe. A sheathing bract of the inflorescence.
Spikelet. The unit of the inflorescence, composed of two glumes and one or more florets.
Sterile. Without pistils.
Stipe. A tiny stalk to an organ.
Stolon. A horizontal stem creeping on the surface of the ground.
Terete. Cylindrical.
Truncate. Ending abruptly, as if cut off.
Turgid. Swollen.
Unisexual. Having only stamens or only pistils.
Villose. Bearing long, soft hairs.
Web. A cluster of slender, soft hairs.
Whorl. An arrangement of leaves or flowers in a circle around the stem.

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Influence of Flooded Soil on Chemical Composition of Annual Ryegrass and Digestibility by Meadow Voles^{*}

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ABSTRACT

Flooding affects mineral composition of pasture grasses, but little is known concerning effects on fiber, organic-acid and amino-acid composition, dry matter digestibility, and mineral absorption by animals. 'Gulf' annual ryegrass (*Lolium multiflorum* Lam.) was grown on a Bucks loam (Typic Hapludult, fine-loamy, mixed, mesic) in a greenhouse to investigate the influence of flooding and 80% field capacity (FC) soil moisture on plant growth and chemical composition. Flooding increased soil pH, tended to increase ($P < 0.10$) soil exchangeable Al (modified aluminon method), and increased Al, Fe, Cu, neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose, alanine ($P < 0.05$), valine and glutamate ($P < 0.07$) concentrations in ryegrass herbage. Magnesium, K, Zn, malate, fumarate ($P < 0.05$), and succinate ($P < 0.07$) concentrations were decreased by flooding. Meadow voles (*Microtus pennsylvanicus*) were fed the forages grown at two moisture levels over an 8-day period to evaluate mineral availability and forage digestibility. Apparent absorption of Mg and K was decreased ($P < 0.05$) in animals fed forage grown on flooded soil, but absorption of Al ($P < 0.12$), Fe ($P < 0.15$) and P ($P < 0.09$) tended to increase. Results suggest that forages grown under flooded conditions have altered amino acid, organic acid, mineral, and fiber concentrations, which could result in lowered performance of animals grazing these forages.

INTRODUCTION

Short-term flooding of pastures occurs frequently during periods of high rainfall, particularly on poorly drained soil. Reduced concentrations of Mg and Ca (Elkins and Hoveland, 1977) and increased Al (Muchovej, Allen, Martens, Zelazny and Notter, 1986) have been reported in forages in response to high soil moisture. Decreased Mg and Ca concentrations in forage grasses due to flooding (Elkins and Hoveland, 1977), high dietary Al (Dennis, 1971; Allen and Robinson, 1980), and increased concentrations of organic acids (Grunes, Stout and Brownell, 1970), have been suggested as contributing to the onset of grass tetany, a metabolic disorder of ruminants associated with deficiency or impaired utilization of Mg. Muchovej et al. (1986) suggested a relationship between organic acids and increased uptake of

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Al by ryegrass under flooded conditions. They proposed a chelation mechanism which rendered Al available and non-toxic to the plant. Information on flooding effects on forage quality, including fiber, organic acid, and amino acid concentrations in grasses is scarce in the literature. Several authors have reported accumulation of various organic and amino acids in roots of plants under anaerobic soil conditions (Jackson and Drew, 1984), but effects of flooding on concentrations in forage plant tops are not well documented.

This experiment was designed to investigate the relative effects of flooding and 80% of field capacity (FC) soil moisture on fiber, organic acid, amino acid and mineral concentrations in annual ryegrass (*Lolium multiflorum* Lam.). The forages were fed to meadow voles (*Microtus pennsylvanicus*) in a digestion trial to further test effects of soil moisture on forage quality.

MATERIALS AND METHODS

A greenhouse experiment was conducted with the surface horizon of a Bucks loam (Typic Hapludult, fine-loamy, mixed, mesic) with a pH of 6.8 and 16, 91, 816, and 70 mg kg⁻¹ dilute acid extractable [Mehlich I (Nelson, Hehlich and Winters, 1953)] P, K, Ca and Mg, respectively. Soil was air-dried, sieved through a 5-mm stainless steel screen, and weighed into plastic pots (12 kg of air-dry soil pot⁻¹). The soil was fertilized with reagent grade chemicals as follows: 150 mg kg⁻¹ N as NH₄NO₃, 75 mg kg⁻¹ P as CaHPO₄·2H₂O, 75 mg kg⁻¹ K as KCl, 15 mg kg⁻¹ Mg as MgSO₄·7H₂O, 5 mg kg⁻¹ Cu as CuSO₄·5H₂O, 15 mg kg⁻¹ Mn as MnSO₄·H₂O, 15 mg kg⁻¹ Zn as ZnSO₄·7H₂O, and 0.5 mg kg⁻¹ B as Na₂B₄O₇·10H₂O, according to soil test recommendations. Fertilizer was mixed with a 600 g subsample of soil from each pot. Amended subsamples were air-dried and returned to pots and total contents were mixed for 5 minutes in a V-shell blender.

Soil moisture treatments were 1) 80% FC and 2) flooding, beginning 21 days post seedling emergence and continuing for 30 days. For flooding, 1-2 cm of water were maintained above the soil surface until plants were harvested. Field capacity was determined by adding water to a compacted column of soil and measuring gravitational water content after drainage downward to dry soil (Sykes and Loomis, 1967). Following fertilizer application, all soils were brought to 80% FC and allowed to equilibrate for two weeks before planting. Watering to 80% FC was performed gravimetrically on a daily basis with distilled-deionized water, and flooding was maintained visually. Soil moisture treatments were replicated 12 times in a completely randomized design.

'Gulf' annual ryegrass was planted at 1.0 g per pot, and plants were thinned to 100 per pot when approximately 5 cm tall. Plants were harvested at soil level, at the end of the flooded period, rinsed with deionized water, freeze-dried, and ground in a stainless steel Wiley* mill to pass a 1-mm screen. Twelve replications per treatment were needed to produce sufficient dry matter for the feeding trial. Within each treatment, forage was randomly composited by weight among three replications for a final number of four replications per treatment for chemical analysis. Data are reported on a DM basis.

* Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the United States Department of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable.

Soil core samples were collected from each pot following plant harvest. Soil was analyzed without air-drying in order to maintain similar moisture conditions to those in the greenhouse. All analyses were adjusted to dry matter basis. Percentage soil moisture (gravimetrically), pH, exchangeable Al using a modified aluminon method (Jayman and Sivasubramaniam, 1974), P (Murphy and Riley, 1962), and Mg, Ca, and K (extraction with NH_4OAc and analysis by atomic absorption spectrophotometry) were determined on soil. Soil pH was determined with a glass electrode in a 1:1 mixture of soil and H_2O after 1 hr equilibration.

Forage was analyzed for neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose (NDF minus ADF), cellulose, lignin (Van Soest, 1963; Van Soest and Wine, 1968), minerals, organic acids and amino acids. Tissue samples were digested with 3:1 $\text{HNO}_3\text{:HClO}_4$ acid (Sandell, 1950) with modifications as described by Muchovej et al. (1986) and analyzed for Al, Fe, Zn, Cu, Ca, Mg, and K by atomic absorption spectrophotometry. Lanthanum chloride was included in dilutions for Mg and Ca analysis. Phosphorus was determined colorimetrically (Fiske and Subbarow, 1925).

For organic-acid analyses, plant material was extracted using a Soxhlet extractor with 80% (v/v) aqueous ethanol. Glutaric acid (500 μl of a 12 mM solution) was added as an internal standard. The extract was concentrated to dryness, resuspended in water, and solvent extracted with chloroform. The aqueous phase was fractionated using cation and anion exchange resins (Stumpf and Burris, 1979), and samples were analyzed by high-performance liquid chromatography (HPLC) using a 300 x 7.8 mm Bio-Rad Aminex HPX-87H[†] organic acids column with a mobile phase of 0.06 N H_3PO_4 and a flow rate of 0.6 ml/min. Organic acids were detected by absorbance at 214 nm.

For amino acid analysis, tissue was extracted using Soxhlet extractors and 65% (v/v) aqueous ethanol. Filtered extracts were passed through a C-18 Sep-Pak (Waters Associates). Fluorescent derivatives of primary amino acids were prepared using *o*-phthalaldehyde (OPA). The reaction solution was prepared by dissolving 50 mg of OPA in 1 ml of methanol, adding 50 μl β -mercaptoethanol, and bringing the solution to a final volume of 10 ml with 0.40 M sodium borate/KOH pH 9.5 containing 0.1% Brij 35. Samples (20 μl) were mixed with 100 μl of the reaction medium. After 1 minute, 20 μl of the mixture were analyzed by using a Beckman model 344 binary gradient HPLC system equipped with a 4.6 X 45 mm, 5 μm Altex Ultrasphere-ODS precolumn and a 4.6 X 250 mm, 5 μm Altex Ultrasphere-ODS analytical column maintained at 45°C following the protocol of Jones, Paabo and Stein (1981). OPA-amino acid derivatives were detected using a Gilson model 121 fluorescence detector equipped with a 9 μl flow cell and filters for excitation at 305 to 395 nm and emission at 430 to 470 nm. Detector range and time constant settings were 0.02 and 0.5, respectively.

Organic acids and amino acids in samples were identified by similarities in retention times to those of pure compounds (Sigma Chemical Company) and by increased peak areas observed upon spiking samples with the individual standards. Peak areas were determined using a Nelson Analytical model 4416X chromatog-

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raphy data system. Quantification was achieved using standard curves generated using the pure reagents.

Two digestion trials were conducted with four male meadow voles (avg. wt. 35.95 g) per treatment fed ryegrass forages from the greenhouse experiment to estimate *in vivo* dry matter and fiber digestibility and apparent mineral absorption. Meadow voles have been suggested to be suitable models for ruminants when evaluating forage of high digestibility (Keys and Van Soest, 1970).

Voles were trapped during December 1983 and January 1984 and placed individually in shoebox cages (12 by 18 by 27 cm) and fed Wayne Lab Chow and water *ad libitum*. Nine days prior to the trial, voles were switched to Wayne Rabbit Chow to increase fiber intake in preparation for the ground ryegrass diet. Seven days prior to each trial, voles were moved to false-bottom, stainless steel metabolism cages for total collection of feces. Trials consisted of a 3-day transition from rabbit chow to ryegrass, a 2-day preliminary period and a 3-day collection period during which total fecal excretions were collected. Animals were blocked by weight, location in the metabolism cage rack and randomly allotted to the two treatments. Voles were maintained in an environmental chamber at 17.2°C, 5% relative humidity and a light/dark schedule of 11:13 hours to minimize variation between trials. Trial variation was not significant, so data from the two trials were pooled. Feed for each treatment was a composite of all harvested, ground forage from each moisture treatment. Nitrogen was determined on the composited forage by micro Kjeldahl (Nelson and Sommers, 1973).

A blood sample was taken from each vole at the end of the trial, from the interorbital sinus, using 0.05 ml heparinized capillary tubes. Blood serum samples were diluted with 0.1% lanthanum chloride and were analyzed for Ca and Mg by atomic absorption spectrophotometry. Feed and feces samples were digested and analyzed for Al, Mg, Ca, K and P as described for the plant samples. Apparent absorption of minerals and apparent digestibility of fiber were calculated from total intake and excretion and analysis of feed and fecal samples.

Plant data were analyzed as a completely randomized design (Helwig and Council, 1979). Animal data were analyzed as a randomized block design.

RESULTS AND DISCUSSION

Soils. Bucks silt loam is a somewhat poorly drained series and commonly occurs in pasture land in Virginia. Soil samples analyzed at the beginning of the experiment indicated a pH of 6.8 and 70, 816, 91, and 16 mg ⁻¹ extractable Mg, Ca, K, and P, respectively. Exchangeable Al was not detectable.

At the end of the treatment period, soil moisture was 19.9 and 36 g 100 g⁻¹ soil for 80% FC and flooded soil, respectively. Soil pH was higher and exchangeable Al tended to be higher ($P < 0.10$) in flooded soil compared to soil maintained at 80% FC (Table 1). An increase in soil pH is commonly observed under flooded conditions. An increase in soil exchangeable Al in response to flooding was reported by Muchovej et al. (1986). The decreased pH in both flooded and 80% FC treated soils, compared to initial values, was probably due to acidity generated by fertilizer application.

Flooded soil contained higher concentrations of exchangeable Ca, Mg, and K than soil maintained at 80% FC. Moisture status had no significant effect on soil

TABLE 1. Soil pH, exchangeable Al and extractable minerals as influenced by 80% field capacity and flooding.

Item	Soil moisture		SE ¹
	80% FC	Flooded	
pH (H ₂ O)	5.25**	5.50	0.04
Exchangeable Al, cmol(1/3Al ³⁺)kg	0.009 ²	0.021	0.004
Extractable minerals, mg kg ⁻¹			
Ca	1171**	1283	20
Mg	117**	134	3
P	17	20	2
K	107**	149	5

** Indicates difference between values within a line ($P < 0.01$).

¹Standard error of means.

²Values were different ($P < 0.10$).

TABLE 2. Yield, fiber and mineral concentrations¹ in annual ryegrass as influenced by 80% field capacity and flooded soil

Item	Soil moisture		SE ²
	80% FC	Flooded	
Dry matter yield, g pot ⁻¹	111.6**	88.8	4.3
NDF, mg 100mg ⁻¹	34.8**	36.7	0.3
ADF, mg 100mg ⁻¹	21.7*	22.7	0.2
Hemicellulose, mg 100mg ⁻¹	13.1*	14.0	0.2
Cellulose, mg 100mg ⁻¹	16.8	18.0	0.6
Lignin, mg 100mg ⁻¹	2.8	2.9	0.4
Mg, mg 100mg ⁻¹	0.37***	0.22	0.01
Ca, mg 100mg ⁻¹	1.24	1.27	0.02
K, mg 100mg ⁻¹	2.75***	2.07	0.08
P, mg 100mg ⁻¹	0.37	0.35	0.01
Cu, mg kg ⁻¹	20***	27	1
Zn, mg kg ⁻¹	118***	92	1
Al, mg kg ⁻¹	213***	515	29
Fe, mg kg ⁻¹	168***	318	16

* **, *** indicate difference between values within a line ($P < 0.05, 0.01, 0.001$).

¹Dry matter basis.

²Standard error of mean.

exchangeable P. Lower concentrations of Ca, Mg, and K in 80% FC soil probably reflected plant uptake of these nutrients.

Plants. Flooded soil decreased DM yield and increased plant concentrations of NDF, ADF and hemicellulose ($P < 0.05$) in ryegrass, compared to soil at 80% FC (Table 2). Cellulose and lignin were not significantly affected by soil moisture. Aluminum, Fe, and Cu concentrations were higher ($P < 0.01$) in plants grown under flooded conditions, while concentrations of Mg, K and Zn were lower ($P < 0.01$) than in plants grown at 80% FC. Calcium and P concentrations in ryegrass were not significantly affected by the two soil moisture treatments. Crude protein was 270 and 227 g kg⁻¹ in forage grown at 80% FC and flooded soil moisture, respectively (data not shown). Based on NRC (1978) recommendations for laboratory animals, the protein levels should have been sufficient for meadow voles.

Reduction in DM yield due to flooding may have been due in part to loss of soil N by denitrification (Ponnamperuma, 1972). In the present study, N in ryegrass averaged 43.2 and 36.3 g kg⁻¹ for 80% FC and flooded soil moisture treatments, respectively. Increased concentrations of Al and Fe, after 30 d flooding, are in agreement with results obtained by Muchovej et al. (1986) with ryegrass grown for 7 weeks in flooded soil in a greenhouse experiment. Cherney and Robinson (1985) found no relationship of soil moisture with Al accumulation by ryegrass grown in a growth cabinet with flooded periods of up to 21 days. Differences in results may be due to cultivar differences, difference in time plants were exposed to flooded soils or to an inherent difference among soils in Al availability under flooded conditions. The depressing effect of flooding on forage Mg concentration has been reported by Elkins and Hoveland, 1977. In the present study, flooding increased Cu and decreased Zn concentrations in ryegrass. Ponnamperuma (1972) reported similar results for Cu and Zn and suggested that for non-calcareous soils, long-term flooding increased Cu and decreased Zn availability.

Concentrations of succinate ($P < 0.07$), malate, and fumarate ($P < 0.05$) decreased while those of alanine ($P < 0.01$), glutamate, and valine ($P < 0.07$) increased in plants grown under flooded conditions (Table 3). Other amino acids identified and quantified in HPLC chromatograms, and citrate, were not significantly influenced by soil moisture.

Changes in permeability of cell membranes due to low soil O₂ may cause leakage of some substances, perhaps partially accounting for the decline in tissue concentrations of organic acids (Stolzy and Sojka, 1984). Organic acids are known constituents of root exudates, but the influence of soil moisture on these constituents is poorly understood. An increase in organic-acid concentration in the soil has been suggested to increase plant Al concentration and reduce Al toxicity (Muchovej et al., 1986). They found increased concentrations of Al in ryegrass with added increments of citric and nitrilotriacetic acid to soil.

The increase in certain amino acids during flooding agrees with results from Labanauskas, Stolzy and Handy (1974), who reported an increase in total free amino acids but a decreased sum of protein amino acids in citrus leaves of plants grown with low, as compared to normal, soil O₂. Free amino acids were measured in our experiment. Increased alanine in root and xylem sap was reported in several plants including pumpkins (*Cucurbita* sp. cv. Mozolevskaya), tomatoes (*Lycopersicon* sp. cv. Bison) and some tree species grown under root anaerobiosis (Hook,

TABLE 3. Organic and amino acid composition¹ of annual ryegrass as influenced by 80% field capacity and flooded soil

Item	Soil moisture		SE ²
	80% FC	Flooded	
Organic acids, mg g ⁻¹			
Succinate ³	77.4	44.6	10.4
Citrate	17.5	15.6	1.2
Malate	36.4*	24.6	3.2
Fumarate	0.07**	0.04	0.01
Amino acids, ⁴ μg g ⁻¹			
Aspartate	21.9	23.4	5.6
Glutamate ⁵	15.2	30.5	4.5
Asparagine	44.1	47.0	7.2
Serine	13.0	20.4	4.2
Alanine	39.2**	57.1	1.8
γ-aminobutyric acid	64.0	80.7	8.0
Valine	9.3*	14.0	1.5
Phenylalanine	48.9	47.6	6.5

* **, indicate difference between values within a line ($P < 0.05$, 0.01).

¹Dry basis.

²Standard error of mean.

³Values were different ($P < 0.07$).

⁴Data represent corrected peak areas 1 standard deviation chromatograms from HPLC for four replicates of each treatment except for asparagine under 80% field capacity soil moisture treatments when only three replicates are represented.

⁵Values were different ($P < 0.06$).

1984). Zemlianukhin and Ivanov (1978) suggested that increased CO₂ concentration, which accompanies ethanol fermentation, favored synthesis of γ-aminobutyric acid via α-ketoglutaric acid and glutamate. In our experiment, increases in alanine and glutamate occurred in response to flooding, but no effect was measured on γ-aminobutyric acid.

Animals. Feeding ryegrass grown with 80% FC or flooded soil moisture to meadow voles had no significant effect on body weight at the end of the trial. Dry matter intake and apparent digestibility of dry matter, NDF, ADF, hemicellulose and cellulose tended toward lower values with forage from flooded soil than in 80% FC soil, but the differences were not significant at the 0.05 level of probability (Table 4). The consistency of the lower numerical values for digestibility of DM and fiber components, coupled with the significant increase in NDF, ADF and hemicellulose concentrations in forage (Table 2), strongly suggest reduced digestibility of these components due to flooded soil.

Intake, fecal excretion, apparent absorption of Mg and serum Mg were decreased ($P < 0.05$) in voles fed ryegrass grown on flooded soil (Table 5). Serum Mg concentrations were 6.1 and 5.2 mg dl⁻¹ in voles fed forage grown with 80% and flooded soil moisture, respectively (data not shown). Intake and apparent absorption of K were decreased ($P < 0.05$) in voles fed forage grown on flooded soil. The bioavailability of P to meadow voles appeared to be very low, but was

TABLE 4. Dry matter intake and digestibility of dry matter and fiber components of ryegrass as influenced by 80% field capacity and flooded soil

Item	Soil moisture		SE ¹
	80% FC	Flooded	
Dry matter intake, mg g ⁻¹ body weight	6.1	5.6	0.5
Apparent digestibility, g 100g ⁻¹			
Dry matter	67.4	64.0	3.2
NDF	54.7	45.1	5.2
ADF	52.6	42.0	5.9
Hemicellulose	58.3	50.0	4.2
Cellulose	51.6	37.8	7.2

¹Standard error of mean.

enhanced in ryegrass grown on flooded soil although forage concentrations and P intake were not significantly affected by soil moisture. Animals fed ryegrass grown on flooded soils had increased intakes of Al and Fe ($P < 0.01$), and tended to show increased apparent absorption of Al ($P < 0.12$) and Fe ($P < 0.15$). Calcium, Cu and Zn intake and apparent absorption and serum Ca were not significantly influenced by soil moisture treatments (data not shown).

Lowered serum Mg may have been related to the decreased Mg intake although the Mg content of the diet (122 mg Mg 100 g⁻¹ diet) was above a dietary level (40 mg Mg 100 g⁻¹ diet) normally recommended for rodents (NRC, 1978). Lowered serum Mg could also have been related to dietary Al levels. Increased dietary Al, particularly when chelated with citric acid, has resulted in decreased serum Mg but had little effect on apparent absorption of Mg in sheep and cattle (Allen and Fontenot, 1984; Allen, Horn and Fontenot, 1986). Even small doses of chelated Al appear to have adverse affects on animals. As little as 5 mg Al kg⁻¹ body weight day⁻¹ as Al-nitrilotriacetic acid resulted in morphological damage to liver and kidney of rats (Ebina, Okada, Hamazaki and Midorikawa, 1984). Rats administered saline or Al as chloride or potassium sulfate were unaffected.

The decline in K concentration in forage could help to offset the adverse effects of decreased Mg in forage for grazing ruminants. Research has shown decreased Mg absorption in ruminants with increasing dietary K (Green, Fontenot and Webb, 1983).

Results of our experiments indicate that ryegrass grown under conditions of high soil moisture may have lower quality due to increased fiber and Al and decreased Mg and organic acid concentrations. The possibility of increased bioavailability of Al and its influence on grazing animals needs further investigation. Animals with elevated parathyroid hormone and/or impaired renal function may be particularly susceptible to adverse effects of ingested Al (Allen, 1987). The lowered K could improve bioavailability of Mg. Further research with animals fed forage grown under field conditions is needed to elucidate these effects.

TABLE 5. Intake, excretion and apparent absorption of minerals¹ of ryegrass as influenced by 80% field capacity and flooded soil moisture

Item	Soil moisture		SE ²
	80% FC	Flooded	
	- mg g ⁻¹ body weight -		
Magnesium			
Intake	2.25**	1.22	0.14
Fecal excretion	0.37*	0.24	0.03
Apparent absorption	1.89**	0.98	0.13
Potassium			
Intake	17.3*	12.0	1.2
Fecal excretion	4.51	3.70	0.33
Apparent absorption	12.80*	8.30	1.07
Phosphorus			
Intake	2.28	1.96	0.17
Fecal excretion	2.49*	1.82	0.18
Apparent absorption	-0.20 ³	0.14	0.11
Aluminum			
Intake	0.12**	0.28	0.02
Fecal excretion	0.10**	0.23	0.02
Apparent absorption	0.02	0.05	0.01
Iron			
Intake	0.10**	0.17	0.01
Fecal excretion	0.09*	0.13	0.01
Apparent absorption	0.01	0.04	0.01

* **, indicate difference between values within a line (P < 0.05, 0.01).

¹Dry matter basis.

²Standard error of mean.

³Values are different (P < 0.09).

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Sediment Denitrification Potential in the Elizabeth River, Virginia

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ABSTRACT

Sediment denitrification potential from two sites in the Elizabeth River estuary was studied over a nine-month period using the acetylene blockage method. Rates of microbial processes in this environment are of interest because of the high concentration of toxics present in some parts of the system. Highest rates were found in the highly polluted Southern Branch of the Elizabeth River with nitrate amended sediment ranging from 2-262 nmol $\text{N}_2\text{O}/\text{h}$ per 20ml of sediment and exhibiting maximal rates during spring and fall. Rates in the Main Stem of the Elizabeth River were lower, with less than 1-85 nmol $\text{N}_2\text{O}/\text{h}/20\text{ml}$ in nitrate amended sediment, and maxima in late fall. Unamended sediment from the Southern Branch denitrified in spring (2-131 nmol $\text{N}_2\text{O}/\text{h}/20\text{ml}$) and fall (1-124 nmol $\text{N}_2\text{O}/\text{h}/20\text{ml}$) only. Main Stem unamended sediment denitrified only minimally in the spring. Sediment denitrification potential was independent of temperature and dissolved oxygen in the water column. Comparison of phytoplankton abundance values and potential denitrification rates suggest that denitrification potential may be stimulated by phytoplankton bloom senescence. Comparison to other published studies shows sediment denitrification potential in the Elizabeth River to be within the range of values reported for other environments.

INTRODUCTION

Denitrification may serve as a mechanism for removal of excess nitrate in eutrophic aquatic environments. Generally denitrification rates are seen to be nitrate limited (Gordon et al. 1986; King and Nedwell, 1985; Oremland et al. 1984), so that in a eutrophic environment denitrification would be expected to increase. However, the presence of toxics could inhibit microbial processes in the sediment, including denitrification.

Pseudomonas and *Alcaligenes* species are considered the major contributors to denitrification in aquatic sediments. In addition, strains of *Bacillus*, *Corynebacterium*, *Micrococcus*, *Achromobacter*, and *Nitrosomonas* denitrify, indicating a wide diversity in bacterial denitrifiers (Knowles, 1982; Payne, 1973). Since denitrification is carried out by many sediment bacteria, it may be viewed as an indicator of the status of the sediment microbial population.

The Elizabeth River is an interesting environment for the study of microbial processes in a heavily industrialized region. Contamination from heavy metals and other toxic compounds such as polynuclear aromatics poses a serious problem to this estuary, and it is considered to be a system under stress (V.S.W.C.B. Gen. Inf.

Bull #557, 1984). The multitude of industries surrounding the river include shipbuilding, naval operations, waste treatment plants, coal facilities, chemical facilities, and power generating plants. The effects of such contamination and industrial activities on microbial processes in this system have not been assessed.

In this study we determined denitrification potentials at two sites in the Elizabeth River over a nine-month time period using the acetylene blockage method. To our knowledge this is the first such study in the Elizabeth River estuary. In order to determine factors controlling sediment denitrification potential, rates were compared to temperature, and dissolved oxygen in the water column. In addition, denitrification potentials at one site were compared to phytoplankton abundance in the water column.

METHODS

Sites and Sampling

Estuarine sediment was obtained from two sites in the Elizabeth River (Figure 1). Sediment was collected using a Ponar Grab (Wildco Instruments) and placed in sterile glass jars for transportation back to the laboratory. Water depth was between 0.9-1.8 m. One site was in the upper reaches of the Elizabeth River Southern Branch, adjacent to a nitrate fertilizer plant. This was an organic rich sediment. In a previous study, water column nitrate at the site was measured at $6.1 \mu\text{M}$ (Alden et al. 1988). Sediment from the second site was taken from the lower reaches of the Elizabeth River in the Main Stem, behind the docks of Norfolk International Terminal. The sediment from this site had patchy areas with relatively high sand content. Water column nitrate at this site was $0.5 \mu\text{M}$ (Alden et al. 1988).

In the laboratory, the sediment was homogenized and diluted with surface water samples (4:1, sediment:water, vol:vol) from each respective site. The slurry was then dispensed in 20 ml portions (graduated cylinder) into sterile 125 ml Erlenmeyer flasks which were then sealed with rubber stoppers and gassed with N_2 for 5 min to obtain anaerobic conditions. Duplicate flasks were prepared for each condition. Acetylene (Union Carbide) was added through the rubber stoppers (which had wells cored out of the top 2/3 portion) by injection to the headspace gas using a 20 ml syringe (Stylex) for a final concentration of 10% (Taylor, 1983). In the last two experiments acetylene was freshly generated in a separate flask by the reaction of calcium carbide and water and added as above. Nitrate additions in the form of KNO_3 (10 mM solution) were made by injection into the slurry to obtain a $100 \mu\text{M}$ concentration in each flask. Sediments were incubated within 3 hours of collection in an incubator-shaker set at 100 rpm and 26°C . Incubation time (time = 0) began with the addition of potassium nitrate (executed immediately after addition of acetylene) in nitrate amended flasks, or, in flasks with ambient nitrate concentrations immediately after addition of acetylene.

For phytoplankton determination, two composite water samples of 15 liters each were taken above and below the pycnocline, using an intake hose and shipboard pump, at a mid-channel station in the Southern Branch, monthly from February through December 1989 (Figure 1). A 500 ml water sample was then taken from each composite sample and preserved with Lugols solution for phytoplankton analysis. A settling and siphoning procedure followed to obtain a

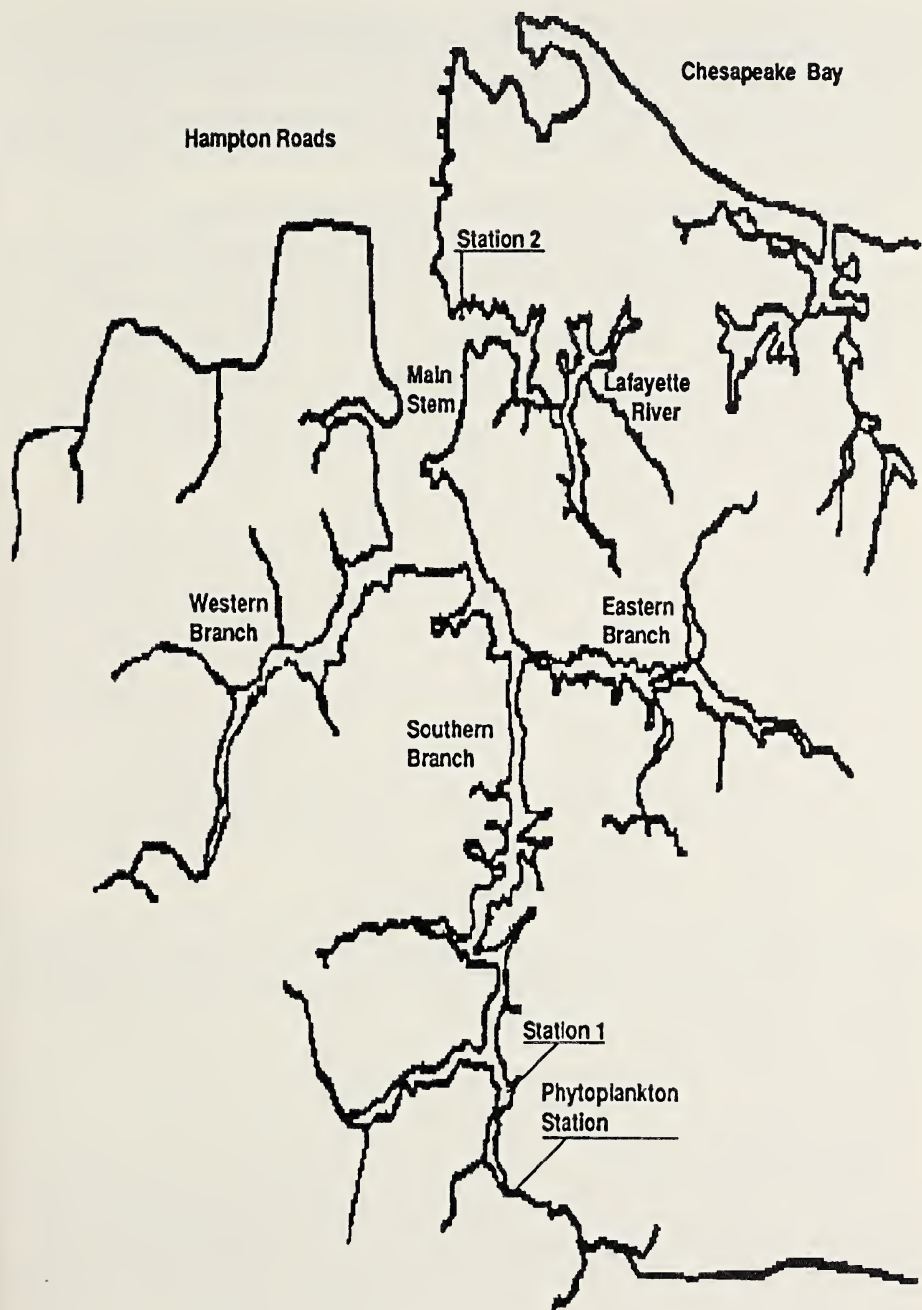


FIGURE 1. Location of sediment sampling sites for the denitrification assay, collection station for phytoplankton analysis, and major tributaries.

20 ml concentrate that was transferred to a settling chamber for examination with an inverted plankton microscope. The entire sample was scanned at 125x for counts of larger net species. A random field and minimum count basis was used at 315x for microplankton and 500x for nanoplankton to obtain an 85% accuracy estimate for these two categories. Mean values of replicate samples were used for the final counts.

Temperature, Salinity, and Dissolved Oxygen Measurements

Measurements of temperature, salinity, and dissolved oxygen (D.O.) were made at the sites before or following collection. Temperature and salinity readings were taken with a YSI S-C-T Meter (model 33) and D.O. readings using a YSI Oxygen Monitor (model 54A) fitted with a Clarke electrode. Both surface and bottom readings were taken for each measurement. Surface readings were taken with the probe immediately below the water surface and bottom readings with the probe directly above the bottom. This was achieved by pulling the probe up 5-8 cm after contact with the bottom. Only bottom readings were analyzed.

Denitrification Measurements and Calculations

Nitrous oxide determinations were made using the acetylene blockage method (Dodds and Jones, 1987; Gordon et al. 1986; Jorgensen, 1986, King and Nedwell, 1985). Corrections for N_2O in solution were made by injecting a representative amount of N_2O to the gas phase of a flask with deactivated sediment (autoclaved and corrected for water loss) and monitoring the subsequent decrease in headspace nitrous oxide. Headspace nitrous oxide concentrations were measured using a Varian 3600 gas chromatograph fitted with a ^{63}Ni electron-capture detector. Samples of the gas phase (0.1 ml) were injected into a 1.84m Porapak Q column set at 60°C using a 0.5ml Glaspak syringe (Becton and Dickinson). Detector temperature was at 300°C and injector temperature at 250°C. The carrier gas (95% argon 5% methane) was set at a flow rate of 30 ml/min. A valve allowed for acetylene venting to prevent damage to the detector.

Nitrous oxide concentration in the headspace gas was measured over time, and rates were calculated using linear regression analysis. Standards were prepared by dilution of 1% N_2O into flasks purged with N_2 . The smallest concentration was prepared by serial dilution in the same manner as above. Two experiments were carried out in which second nitrate additions or glucose (injected as solution) were made to sediments in which denitrification had slowed or stopped.

RESULTS

Southern Branch Station

Temperature readings ranged from 11°-16°C in April and December to 32°C in late July. Dissolved oxygen levels were lowest in August (2.9 ppm) and highest in April and December (7.0, 8.9 ppm, respectively). Denitrification rates were independent of temperature ($r = -0.22$) and oxygen ($r = 0.43$) in the overlying water. Figure 2 shows a typical result of the denitrification assay.

Potential rates exhibited maxima in spring and in autumn (Figure 3). Un-amended sediments denitrified in late spring (131 nmol N_2O /h per 20ml sediment) and early autumn (124 nmol N_2O /h/20ml), with lower rates than amended sediments, except on Sept. 27 when ambient and amended sediments denitrified at approximately equal rates. The maxima for amended sediments, in nmol N_2O /h

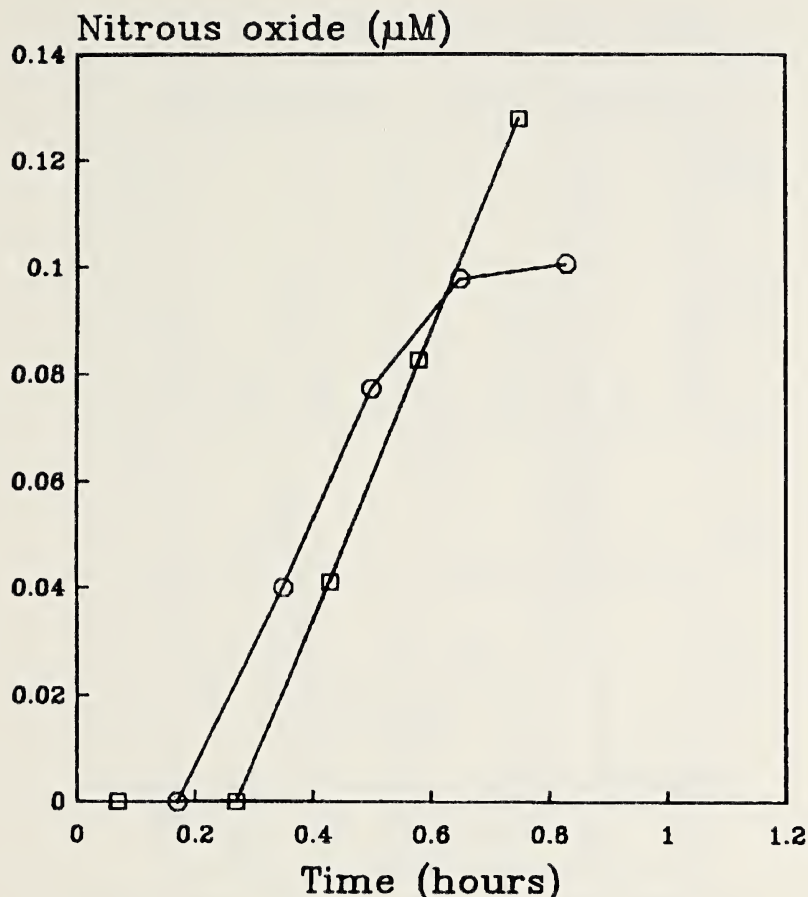


FIGURE 2. Results of a typical denitrification assay (week 26) from (CIRCLE) the Southern Branch and (SQUARE) Main Stem nitrate amended sediment. KNO_3 (0.2 ml, 10 mM solution) was added to 20 ml sediment. Results represent mean of duplicate flasks incubated at 26°C .

per 20ml sediment, were 262 on May 24, 117 on Sept. 27, 107 on Oct. 11, and 159 on Dec. 6. The rates ranged from 1-131 $\text{nmol N}_2\text{O/h/20ml}$ in unamended sediment and 2-262 $\text{nmol N}_2\text{O/h/20ml}$ in amended sediment. Sediments in which denitrification had slowed or stopped resumed denitrification following a second addition of nitrate. Sediments receiving glucose did not respond.

The dominant contributor to phytoplankton biomass in this region was the diatoms (Bacillariophyceae). Data showing diatom abundance and denitrification potential are represented in Figure 4.

Main Stem Station

Temperature and D.O. readings for this site were similar to the Southern Branch station, though for two dates (6/14, 7/12) D.O. readings are not available due to equipment failure. Denitrification rates in Main Stem sediment do not correlate to water column temperature ($r = -0.13$) or D.O. ($r = -0.08$).

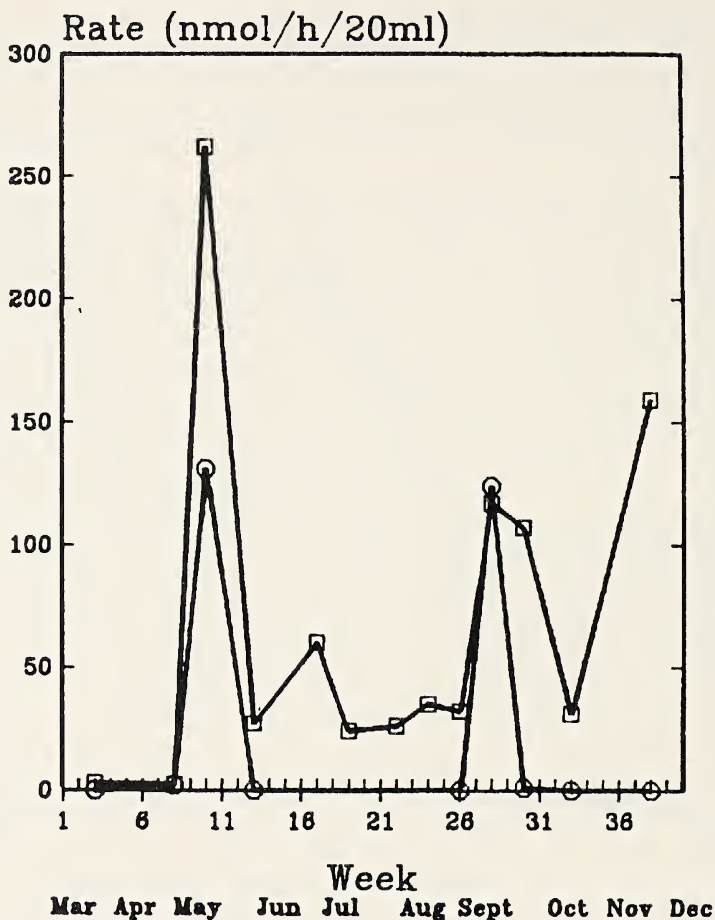


FIGURE 3. Variation in rates of nitrous oxide production during the study period starting with week 1 (March 19) in the Southern Branch. Legend is as follows: (CIRCLE) flasks with ambient nitrate concentrations, (SQUARE) flasks with added nitrate.

The overall potential rates for Main Stem sediment were lower than those for the Southern Branch. Only nitrate amended sediments denitrified (Figure 5), except on May 11 when unamended sediment produced N_2O at a minimal rate. The sediment had a gradual increase in denitrification potential with the progression of summer, then a relatively marked increase during autumn. The maxima for this site occurred in early fall (85 nmol N_2O /h per 20ml sediment on Sept. 27, 77 nmol N_2O /h/20ml on Oct. 11) and early December (58 nmol N_2O /h/20ml on Dec. 6). Potential rates (amended sediment only) ranged from less than 1-85 nmol N_2O /h/20ml. As in Southern Branch sediment, subsequent addition of glucose had no effect, whereas addition of nitrate caused the sediment to resume denitrification. The sediment did not denitrify on May 24, even with added nitrate.

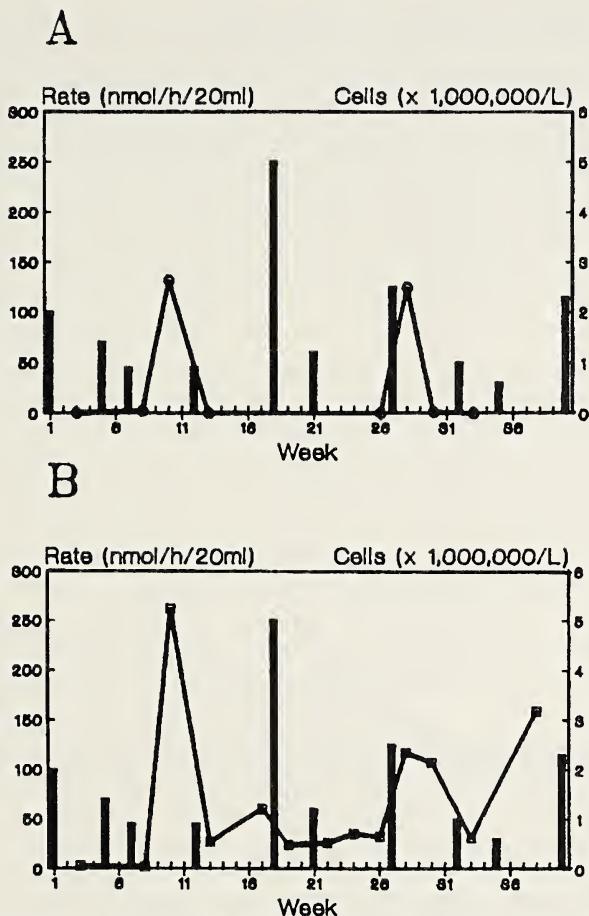


FIGURE 4. Denitrification potential in Southern Branch sediment (line) and Bacillariophyceae numbers (bars), for (a) sediment with ambient nitrate levels, and (b) sediment with added nitrate.

DISCUSSION

Overall the rates for the Southern Branch were greater than those for the Main Stem, with much variability of potential denitrification rates during the study period. In contrast to Gordon et al. 1986, rates did not show the expected variability with respect to seasonal changes. This is consistent with the findings of other studies (Anderson, 1977; Caveri and Phelps, 1977). The rates did not increase with increasing water temperatures and decreasing levels of dissolved oxygen as expected. The Southern Branch even exhibited high potential rates during low temperatures and high D.O. levels (May 24, Oct. 11, Dec. 6; D.O. and temperature data not shown). The maxima in spring and fall both occurred at intermediate levels (18-25°C, 5-6 ppm D.O.) Rates for both Southern Branch and Main Stem sediment were usually nitrate limited, the exception occurring on Sept. 27 (Southern Branch), when amended and unamended sediments denitrified at nearly equal rates, indicating saturation of the system.

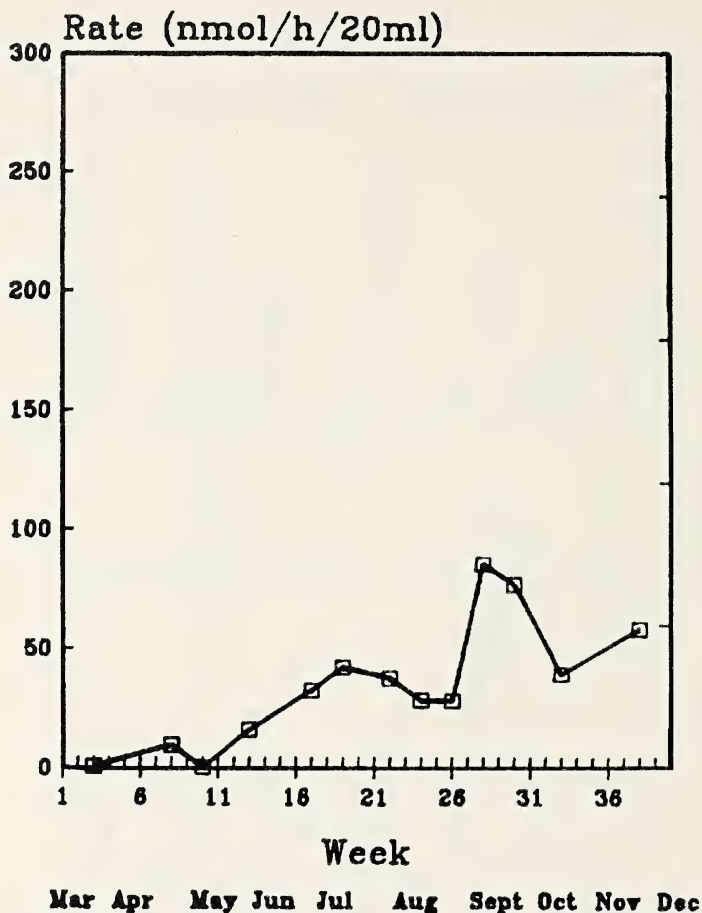


FIGURE 5. Variation in rates of nitrous oxide production in nitrate amended Main Stem sediment, starting with week 1 (March 19). Sediment with ambient nitrate levels denitrified only minimally in the spring (not shown).

The rates from Southern Branch sediment were similar to those reported by Oremland et al. 1984 in San Francisco Bay sediment. In nitrate amended sediments the potential rates were 32-190 nmol $\text{N}_2\text{O}/\text{h}/20\text{ml}$ (San Francisco Bay) and 2-262 nmol $\text{N}_2\text{O}/\text{h}/20\text{ml}$ (Southern Branch). For sediments with ambient nitrate concentrations having undergone comparable treatments, the rates were 5-80 nmol $\text{N}_2\text{O}/\text{h}/20\text{ml}$ (San Francisco Bay) and 1-131 nmol $\text{N}_2\text{O}/\text{h}/20\text{ml}$ (Southern Branch).

The potential rates from the study by Gordon et al. in Everglades peat sediment were comparable to the rates from Main Stem sediment (nitrate amended) reported in this study. The rates were 12-60 nmol $\text{N}_2\text{O}/\text{h}/20\text{ml}$ (Everglades peat) and 1-85 nmol $\text{N}_2\text{O}/\text{h}/20\text{ml}$ (Main Stem). Rates reported for marl sediment in the Everglades, with rates ranging 36-396 nmol $\text{N}_2\text{O}/\text{h}/20\text{ml}$, surpassed those of the eutrophic Southern Branch (2-262 nmol $\text{N}_2\text{O}/\text{h}/20\text{ml}$).

Gordon et al. (1986) reported increased denitrification rates when water levels receded and a periphyton mat came to rest on the sediment. This was suggested

to be due to input of organic material from the deposition of the cyanobacterial mat. We suspected therefore that the productivity of phytoplankton, which constitute the major autotrophic component of the Elizabeth River (O'Reilly and Marshall 1988), could influence the denitrification potential of the sediment.

The spring and fall maxima of both amended and unamended sediments appear between peaks in phytoplankton abundance in the Southern Branch region (Figure 4). A possible explanation for this effect is low availability of nitrate during bloom periods. Another possibility is that as the phytoplankton blooms recede and particulate organic matter is deposited on the sediment, N mineralization and nitrification in combination contribute to increasing sediment nitrate levels, thus increasing denitrification potential.

Denitrification potential is also dependent on the activities of other nitrate-utilizing biochemical pathways. Studies have found that denitrification competes with nitrate ammonification (dissimilatory reduction) and nitrate assimilation, which deplete nitrate levels (Jorgensen, 1986; Rher and Klemme 1989; Wyer and Hill, 1984). Studies on marine sediments indicate that nitrate ammonification is maximal in late summer when denitrifying processes are minimal (Jorgensen, 1986), and that equal reduction of nitrate to ammonium and nitrous oxide may occur (King and Nedwell, 1985). These competing pathways may have a small effect on denitrification potential with elevated nitrate levels, but they become significant competitors in nitrate limiting conditions. Low denitrification potentials observed during the summer in this study may therefore reflect successful competition for available nitrate by other nitrate utilizing pathways.

In Main Stem sediment, the overall diminished rates (compared to the Southern Branch) could be attributed to the generally lower nutrient content of the station and the higher flushing characteristics of this area. This site also displayed patchy areas of extremely sandy sediment, possibly explaining the absence of denitrification activity on May 24.

In summary, Southern Branch spring and fall maxima in denitrification potential appear to correspond with the decline of phytoplankton blooms in the water column. These data suggest an interaction between denitrification potential at this site and phytoplankton production. Comparison of rates to other environments in the Everglades National Park and in San Francisco Bay indicates that sediment denitrification potential in this stressed water system is within the range of reported values for both polluted and pristine environments. Denitrification potential in the sediments is, therefore, maintained in the presence of toxics in the sediment. Further studies are needed in order to determine the effect of contamination in this estuary on other microbial processes and the general influence of phytoplankton productivity on sediment denitrification rates and potential in estuarine systems.

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Applications in Biotechnology: Field Testing Genetically Engineered Plants and Microorganisms

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ABSTRACT

Genetic manipulation of plants and microorganisms through molecular biology procedures has proceeded rapidly, resulting in expanding numbers of field tests and the initiation of numerous commercial development ventures. Currently, ninety-one field tests of genetically engineered plants (GEPs) and eleven of genetically engineered microorganisms (GEMs) have been conducted for at least one year, and the number of applications for additional tests is increasing. A regulatory framework has been developed between the U.S. Department of Agriculture (for GEPs) and the Environmental Protection Agency (for GEMs); this framework has functioned effectively in the application and approval process for each test. The lesser concern over field tests of GEPs (because of ease of containment) has resulted in greater numbers of approved tests than has been the case with GEMs. This paper summarizes the current status of each approved field test--geographical location, plant species and/or microorganisms involved, and the engineered genetic trait.

INTRODUCTION

The potential agricultural benefits that may result from biotechnology have been widely debated by the scientific community, public interest groups and federal regulatory agencies. Most predictions point to agriculture as one industry that will reap many of the greatest rewards from new developments in biotechnology, and more efficient and environmentally safe food and fiber production is a major potential benefit (Dines, 1985). During the 1980's, concern over widespread use of pesticidal chemicals in the environment was a major factor in promoting molecular research to develop plants and microbes that would either require fewer treatments or serve as alternatives to chemical applications.

Genetic manipulation through recombinant DNA procedures has the potential to increase the effectiveness of engineered plants and microbes and to expand the range of soils and environmental conditions into which the plants and microbes could be released (Betz, 1988). There are now several examples of successes in engineering plants for enhanced resistance to specific pathogens, insect pests, or herbicides which are currently being field tested (Cramer and Radin, 1990). The development of engineered microbes that will contribute to plant productivity by eliciting more rapid growth or protecting plants from pathogens or pests has also proceeded rapidly (Vaughan, 1988). While concerns have arisen that engineered plants and microbes could have the potential to cause environmental problems

after field release (Curtis, 1988), the evidence obtained from the detailed review process for approval of such releases indicates that foreseeable problems can be avoided (Milewski, 1990). This paper summarizes the field tests of engineered plants and microbes that have been conducted to date.

I. GENETICALLY ENGINEERED PLANTS (GEPs)

The development of genetically engineered plants (GEPs) offers potential commercial opportunities in a wide range of applications (Cramer and Radin, 1990). The use of GEPs also generates difficult questions for regulatory agencies as well as the public and the scientific community regarding the safety of field testing on a broad agricultural scale. The review and approval process must contend with the twin objectives of allowing society to benefit from new products and minimizing risks to public health and the environment (Curtiss, 1988; Parry and Miksche, 1988).

Compared with conventional processes such as plant breeding and field-based germplasm screening, genetic engineering techniques have contributed, for several crops, faster and more accurate means of developing new plant lines and identifying important plant genes (An et al, 1986). The ability to screen plant material for the specific genes of interest can dramatically shorten the time required to produce new crop varieties. Most strikingly, it is now possible with genetic engineering to transfer genes between very different kinds of organisms--something not previously achievable (Vaeck et al., 1988). For example, the use of transposons to both remove and insert specific genes has permitted the transfer and expression of genes between unrelated plants and between plants and microorganisms.

The U. S. Department of Agriculture (USDA) has instituted a rigorous evaluation process under the Federal Plant Pest Act that reviews each request to field test a GEP (Miksche and Chandra, 1988). If the GEP contains genetic material from a microorganism, then the U.S. Environmental Protection Agency (EPA) also participates and conducts a joint review with USDA (Betz, 1988). The appropriate state Department of Agriculture is also contacted by USDA and may elect to hold a separate review (Milewski, 1990). To date, 91 GEP tests have been approved and initiated; others are now in the final review process (Table 1).

Herbicide Tolerance: To date, 36 field tests of GEPs have been conducted with five crops in 12 states; the first tests were initiated in 1987. The source of the resistance genes is usually a plant, such as tobacco or petunia, that is naturally tolerant to the herbicides. Since many bacteria are tolerant to herbicides, some GEPs have received their resistance genes from bacteria (Cramer and Radin, 1990). Genetic tolerance has been successfully transferred for several classes of herbicides including bromoxynil (Buctril, by Hoechst AG), glufosinate (Basta, by Rhone-Poulenc), glyphosate (Roundup, by Monsanto), and sulfonyleurea (Classic and Express, by Dupont).

Insect/Pest Resistance: At present, 45 field tests of GEPs have been conducted with eight crops in 20 states, and the first tests were initiated in 1988. The goal of genetically engineering crops for insect/pest resistance is to allow more uniform control of insects and pests and to incorporate control technologies that are not dependent on a chemical application. The source of the resistant genes is usually microorganisms (bacteria and viruses) that are natural pathogens of insects (Bishop et al., 1988). The GEP is then able to use the microbial genes to produce

TABLE 1. GEP Field Tests, Target Crops, and Locations

Engineered Trait	Number of Tests	Target Crops	Test Locations
Herbicide Tolerance	36	Alfalfa, Cotton, Soybean, Tobacco, Tomato	AL,AR,AZ,CA,DE,FL, HI, IA, IL, IN, KY,MN,MO,MS,NC, TN,VA
Insect/Pest Resistance	45	Alfalfa, Cantalope, Cotton, Cucumber, Potato, Squash, Tobacco, Tomato	AL,AZ,CA,DE,FL, GA,HI,IA,ID,IL, LA,MD,MN,MS, TX, NE,NC,NY,WA,WI
Wound Induced Enzymes	5	Tobacco, Poplar	DE ,IA ,IA
Delayed Fruit Ripening	5	Tomato	CA, FL, HI

a toxin that kills feeding insects. The discovery of important viral resistance mechanisms in bacteria and the ability to locate the responsible genes has been the basis for conferring viral resistance in many GEPs.

Genetic resistance has been successfully transferred in plants for several classes of beetles (Coleoptera) and caterpillars (Lepidoptera) and plant viruses (leaf roll and mosaic viruses)(Vaeck et al., 1988).

Wound Induced Enzymes: To date, five field tests of GEPs have been conducted with two crops in three states; they were initiated in 1988. The goal of genetically engineering crops for the production of wound induced enzymes is to enable the plant to repair cellular damage caused by pests, weather (hail), or mechanical injury. The source of the enzyme production genes is potatoes, and the genes have been successfully transferred (with bacterial transposons) to tobacco and poplar. This research is proprietary to Iowa State University, and little information is available to date.

Delayed Fruit Ripening: At present, five field tests of GEPs have been conducted with one crop (tomatoes) in three states; these were initiated in 1989. The goal of genetically engineering crops for delayed fruit ripening is to allow most of the crop to ripen over a short time span, and to permit a faster and more efficient harvest. The source of the genes that delay fruit ripening is from a non-commercial tomato variety, and the genes were transferred with bacterial transposons (which makes the recipient tomato variety a GEP).

GEP Summary: Generally, the results of the field tests shown in Table 1 have been positive and have demonstrated that GEPs can be effective under field conditions. Several herbicide tolerance studies will be in their fifth year this season, and some of the GEPs in those tests have already been entered into the commercial development process. The number of approved GEP field tests is increasing each

season, and tests with genetically engineered corn and wheat are anticipated in the near future. The first test of a GEP in Virginia occurred during the 1990 field season. The GEP was a soybean resistant to Roundup (Monsanto), and the test was conducted on a farm near Emporia, in Greensville County. The test was reviewed and approved by USDA and the Virginia Department of Agriculture and Consumer Services.

II. GENETICALLY ENGINEERED MICROORGANISMS (GEMs)

In the future, much of the leading biotechnological research that applies to agriculture will involve the development of genetically engineered microorganisms (GEMs) that are designed to perform specific functions. Compared with conventional procedures for manipulating microorganisms, genetic engineering techniques have made it possible to transfer genes between unrelated bacteria and to provide recipient bacteria with characteristics that are not naturally found (Joos et al., 1988). As with GEPs, the use of transposons have been the basis for the creation of most GEMs, and transposons have provided the means for identifying important microbial genes and then quickly developing GEMs with novel properties.

Some of the proposed functions of GEMs include enhancement of nitrogen fixation (Gerhold and Stacey, 1990), destruction of weeds, repression of fungal pathogens (Howell, 1990), control of insect pests (Bishop et al., 1988), or biodegradation of pesticide residues (Brosten, 1987; GAO, 1988). Concerns over the difficulty of containing GEMs in the field has resulted in smaller numbers of approved tests than has been the case with GEPs (Curtiss, 1988). Although no products presently sold for field use contain GEMs, several field studies with GEMs are currently in progress (Table 2).

Reduced Frost Damage: Two field trials in California involve the same organism: a strain of the bacterium *Pseudomonas syringae*. This bacterium resides on plant leaf surfaces and promotes the formation of ice crystals at temperatures near freezing. It is this formation of ice crystals that causes damage to plant cells from frost injury. Using recombinant-DNA techniques, a mutant strain that lacked the ability to enhance ice formation was developed. This mutant strain is the "ice-minus bacterium" that has received such wide coverage by the press. These mutant GEMs, when applied to plants, reduce ice formation at near-freezing temperatures and protect plants from frost injury. If successful, this product will protect sensitive crops from early frosts and will extend the growing season (Lindow, 1990).

The first test of the product was conducted in April 1987 at Brentwood, CA by Advanced Genetic Sciences, Inc. A suspension of "ice-minus" GEMs was sprayed on strawberry plants. A second test was conducted on potatoes in May of that year near Tuelle Lake, CA by scientists from the University of California. These two experiments were the first GEM field test to be conducted in the United States (Lindow and Panopoulos, 1988). Both tests were vandalized by groups claiming to represent environmental concerns. Each test was replanted, the evaluations were continued, and the tests are now in their fourth year of field trials. To date, the only environmental damage that has been documented as occurring in association with these field tests has been the damage sustained from the concentrations of herbicides dumped on the potato trial by vandals.

TABLE 2. GEM Field Tests, the Engineered Organism, Target Crops, and Test Locations.

Engineered Trait	Engineered Organism	Target Crops	Test Locations
Reduced Frost Damage	<i>Pseudomonas syringae</i>	Potatoes, Strawberries	CA
Biological Insecticides	<i>Clavibacter xyli</i>	Corn, Rice	MD, MN, NE NY, IL
Enhanced Nitrogen Fixation	<i>Bradyrhizobium japonicum</i> and <i>Rhizobium meliloti</i>	Alfalfa Soybeans	IA, WI, LA
Environmental Monitoring	<i>Pseudomonas aureofaciens</i>	None	SC, WA

Biological Insecticides: Crop Genetics International, Inc. has been conducting GEM field tests in five states. The organism *Clavibacter xyli*, a bacterium that resides in the water-conducting vessels of grass family plants, has been "designed" by recombinant DNA to control the European Corn Borer in corn. This GEM was "created" by inserting genes from another bacterium, *Bacillus thuringiensis*, that produce a toxin lethal to the European Corn Borer. The *Bacillus thuringiensis* bacterium has been known and used to control lepidopterous insects for many years; however, the bacterium will not survive long on plant surfaces (Carlton, 1988). By the incorporation of the toxin genes from *B. thuringiensis* into *Clavibacter xyli*, an endophytic bacterium of corn, it is hoped that season-long control of European Corn Borer can be obtained.

Enhanced Nitrogen Fixation: In 1988, a test of a GEM was established by Biotechnica International in Peppin County, WI. The organism is a strain of *Rhizobium meliloti* that has been genetically altered to fix greater amounts of nitrogen than strains that are currently available. Members of the genus *Rhizobium* are responsible for nodule formation on the roots of legume plants (e.g., soybeans, alfalfa, peanuts, clover, peas, and vetch). It is within these nodules that the bacteria "fix" atmospheric nitrogen into an organic form that the plant can use for growth (Gerhold and Stacey, 1990). This GEM (*Rhizobium* mutant) carries extra copies of the genes that direct the nitrogen fixation process, and in greenhouse tests, yields of alfalfa hay were enhanced. Field testing of this GEM on alfalfa is scheduled to last three years. Biotechnica International has also developed similar GEMs of *Bradyrhizobium japonicum*, the nitrogen fixing strain for soybeans, and has received approval for three additional field tests on soybeans in Iowa, Louisiana, and Wisconsin. These tests were approved and initiated in the summer of 1990.

Environmental Monitoring: In 1987, a field test of a GEM was established near Blackville, SC, in a cooperative effort between Clemson University and the Monsanto Corporation. The GEM tested is a strain *Pseudomonas aureofaciens* that contains genes obtained from another bacterium, *Escherichia coli*. These genes were transferred by recombinant DNA techniques into the *Pseudomonas* strain, and the function of the genes conferred novel properties to the *Pseudomonas* that allowed it to be "tracked" in the soil environment (Drahos et al., 1988). This field trial is scheduled to be conducted for four years in a wheat-corn-soybean rotation. The GEM being tested was not designed for a specific commercial purpose, but rather as a root colonizer to evaluate techniques that are used to "track," recover, and identify a GEM from the environment. An additional test evaluating this GEM as a biological control agent to protect wheat roots from diseases was approved in 1990 and initiated in the state of Washington.

GEM Summary: Each of the GEM tests described above has received vigorous review and evaluation by EPA, the USDA Animal and Plant Health Inspection Service (APHIS), and the state Department of Agriculture in each state where a test has been requested (Betz, 1988; Miksche and Chandra, 1988; Milewski, 1990). In addition, panels of university experts were formed to review each test application (GAO, 1988; Office of Science and Technology Policy, 1986; US-EPA, 1986).

The number of requests to conduct GEM field tests is increasing now that a regulatory framework is in place to evaluate and approve such requests. Activity in the development and testing of GEMs in the field is bringing the day closer when commercial products containing GEMS will be available to the farmer. Although no GEM field tests have yet been conducted in Virginia, the time is not far off when such tests will also be conducted in the Commonwealth, and GEM-derived products will be available to our growers. While it is unlikely that biotechnology products (GEMs and GEPs) will revolutionize agricultural practices, the materials developed through biotechnology will expand production options available to farmers, furthering their capacity to remain profitable and competitive in international markets while reducing contamination of food products and the environment by pesticide residues.

ACKNOWLEDGEMENTS

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**VIRGINIA ACADEMY OF SCIENCE
COUNCIL MINUTES**

Friday, May 25, 1990

George Mason University

The meeting was called to order by President Richard Brandt at 9:15 A.M.

Members present were Richard Brandt (President), Gerald Taylor (President-elect), Elsa Falls (Secretary), Michael Bass (Immediate Past-president), Dean Decker (Director, VJAS), Ertle Thompson (AAAS Representative & Chair of Science Education Committee), Blanton Bruner (Executive-Secretary/Treasurer), James Martin (Editor VJAS), Jim Murray (Past-past-past-president & Chair of Awards Committee), George Umberger (Chair of Local Arrangements Committee for George Mason University meeting), Stewart Ware (Past-past President), Carvel Blair (Councilor, Environmental Science Section), Bill Banks (Past-past-past-president and Chair of Nominations Committee), Hugo R. Seibel (Anatomy Department, MCV/VCU), Lisa Alty (Councilor, Medical Science Section), Golde Holtzman (Chair of Local Arrangements Committee for 1991 VPI meeting), Vera Remsburg (VAS Representative Trustee to the Science Museum of Virginia), Carolyn Conway (Treasurer), Frank Leftwich (Chair of Constitution and Bylaws Committee), Rae Carpenter (Chair of Trust Committee), and Jim O'Brien (Chair of Publicity Committee).

President's Report by Richard Brandt.

1. I am happy to announce that Carvel Blair is going to each college and university that he can to tell the officials what the Academy and Junior Academy does.
2. We must arrange our meeting schedule after VPI for as many years in the future as possible. Gerald Taylor has a draft copy of a letter that is going to be sent to a number of universities. The committee that has the responsibility for doing that is myself (president), Gerald Taylor (president-elect), Michael Bass (immediate past president), Stewart Ware (past-past-president), and Bill Banks (past-past-past president).
3. We need to increase the membership of this Academy. Carvel's travel is going to help. We are going to have to use the people on Council and the Section Secretaries. We will try to reestablish in which section each member is interested. Possibly, make \$1.00 per member available to their section, in addition to the current \$100.00, so that there is some advantage for a section to expand.
4. Jim O'Brien will be our Publicity Committee chair. We are going to use the section secretaries and chairman in a possible newsletter format. Vera Remsburg has pointed out that she feels that the Academy is losing contact with each other. I agree, we have to find better ways of drawing younger people into the Academy.

5. The Directory will be available for distribution hopefully by July 15. Jim Martin and I have also talked about going back to one of the older type of directories that publishes former awards, Fellows, etc.

6. At this meeting, we are going to establish the dates of all of our Council and Executive Committee meetings for the year.

Local Arrangements Committee Report by George Umberger.

An estimated 864 total attendance for the VJAS, about 900 compared to about 1059 last year, according to Tom Hass figures. We were significantly higher in overnights; 675 this year compared to 437 last year. The VAS is about the same as last year; our estimate around 350 with people still coming in today. Totals, 1200-plus this year compared to 1450 last year. Biggest problem here was space. Public relations had a couple press releases. The winners that participated in the VJAS contest are to be announced in their local newspapers. Some suggestions for next year were given. President Brandt noted that the final report is due to Mr. Bruner as soon as possible, including a copy of the manual that Umberger developed.

Vera Remsburg moved, seconded by Jim O'Brien, that Council thank George Umberger and his committee for an excellent job and that it be recorded in the minutes. **Motion Carried.** Michael Bass states, On behalf of the Academy, I present George with an acknowledgement of its deep appreciation of service to the Academy as Local Arrangements Chairman and to his staff.

Executive Secretary/Treasurer's Report by Blanton Bruner. No report.

Junior Academy of Science Report by Dean Decker. No report.

Virginia Journal of Science Report by Jim Martin.

Jim Martin passed around a paper showing the computer the Academy and Junior Academy purchased and a list of software that the Academy owns. Dean Decker noted that we are shopping for an optical scanner, that will make a lot of the work go faster.

The Visiting Scientists Program was reviewed and discussed. The director, Harold Bell, is doing a fine job.

Standing Committee Reports

Reports were presented at Council Wednesday, May 23. Committee Chairs or representatives indicated there was little to add to their previous reports.

Trust Committee Report by Rae Carpenter.

Rae Carpenter passed out a report in which the auditor by his notes tells what has happened in the general fund, the research fund and the Bethel High School fund. In the general funds, we have two investments that are primarily bonds and two that are primarily common stocks, split is not exactly 50/50. The Fellows fund is a part of the operating fund and is invested in about half stocks and half

bonds. The Research fund is invested, split between common stocks (small fraction) and bond type instruments (bigger fraction). The Bethel High School fund, as of last December, has been completely segregated from every other Academy fund and consists of two Eastman Kodak bonds. (They pay off twice a year and that money is put into a money market fund and held until Bethel gives us instructions as to whom the recipient of their scholarship will be.) The Bethel fund has been source of some problem in the past but we now have that cleared up. I am reporting to the principal of Bethel High School two or three times a year with a run-down of how much interest is in the money market fund and so forth... All of the awards funds for Junior Academy have been put into the VJAS endowment, a common stock fund. The principle thing that should be recognized about all of these funds is, if it is a bond fund, the principal is not absolutely secure but it is very safe. The price of these securities will go up and down and in some cases we have been getting a return of principle as part of the yield that is paid out each year. The mutual funds (Washington Mutual and Investment Company of America, which are the two that we have that are common stock funds) are somewhat more volatile and therefore the price during the year is going to go up and down, but the general trend over many years has always been up. How much up depends on what time period you take. The last 5 years, both of the funds have grown at a rate of 20% or better, not each year but spread over the 5 year period. Right now the Dow Jones Industrial averages is at the highest it has ever been and consequently our stock values in those common stock funds are the highest that they have ever been. Therefore, in the next report, you shouldn't be surprised if you see that their worth has gone down some, instead of up. The Academy is in this for the long term. A sales of some securities was made last year in an attempt to realign the investments in order to include more common stock to have some offset against inflation... Discussion followed.

Rae Carpenter reported that a gift of \$500 was received in March from Mrs. Roscoe Hughes with the understanding that the VJAS Director may use the income to supplement that from some of the other funds which are currently insufficient to support scholarly awards. Discussion followed.

President Brandt congratulated Rae Carpenter for doing a magnificent job.

In response to a question, Rae Carpenter indicated that we would need just about double our current funds if we were to have a two year surplus. For the money to double, at interest rate of 10-12%, it would probably take 6 years for principal to double. Blanton Bruner stated that he had read that a prudent organization should have a separate surplus for one year, and he would not be surprised if the Academy is not approaching a year and a half.

Publicity Committee Report by Jim O'Brien, Chair.

People have asked for press packages. Some changes are needed in the certificates of appreciation. Discussion followed. President Brandt asked Jim

O'Brien to make the necessary changes and submit expenses to Mr. Bruner. Jim O'Brien requested that every new officer write a press release.

Sending out a newsletter was discussed. Two issues would be strictly Academy news, sent to every member regardless of section and sent to department heads of every science and technology department in colleges, universities, and some corporations. Other issues would come at critical points in the year as ways of reinforcing calls for papers, election ballots, etc. Additional details were presented. Discussion and suggestions followed. The Council informally supported the development of the newsletter.

A lengthy discussion related to publication of minutes followed. The highlights of the minutes should be summarized in the Journal, including a summary of the motions. A summary of motions may be printed in the newsletter to show actions taken by Council.

Science Museum of Virginia Report by Vera Remsburg.

Clarification on membership on Council for representative to the Science Museum was requested. Gerald Taylor read page 4 of the November Council minutes, "The motion was that the member of the VAS who has been proposed by the VAS and who is appointed by the Governor to be a trustee of the Science Museum of Virginia be a member of Council." Arthur Burke restates this to say, "The intent of the motion is that the person who is appointed by the governor is a trustee of the Science Museum of Virginia and who is an Academy member, however he got there, becomes a member of Council." Frank Leftwich (Chair of Constitution and Bylaws Committee) reads Articles XII, Section 6 of Constitution: "Council may establish appropriate administrative positions and employ such personnel as may be required. Term of office, the duties, or remuneration of such personnel shall be described by Council." Rae Carpenter notes that the President can always appoint an ad-hoc committee without authority of Council, and can always invite people to attend the Council meeting. President Brant states that for now, that position as declared by the President is an ad-hoc member of Council. Chairman of ad-hoc committees do not vote. Vera Remsburg is Chairman of the Committee on Science Museum, an ad-hoc committee of one. Frank Leftwich will look into exact wording to establish whether representative should be an ad-hoc or regular member of Council. Frank Leftwich is to report on that at the next meeting of Council.

Section Reports Brief section reports from Medical Science Section, Biology Section, and Psychology Section were presented.

Meeting Dates for 1990-91.

The Executive Committee meeting at Virginia Tech, October 13, Fall Council meeting at University of Virginia, November 4, (Council meeting will be at 1:00 pm, the Executive Committee meeting will be at 10:00 am), site meeting with Local Arrangements Committee at Virginia Tech in January, Spring Council Meeting at Virginia Tech, March 2, 1991 (Council meeting will be at 1:00 pm, the Executive Committee meeting will be at 10:00 am), and Annual Meeting, May 21

- 24, 1991 (Executive Committee and Council meeting, Wednesday the 22nd, and Council meeting, Friday the 24).

Discussion of Propose Change of By-laws.

Jim Murray indicated that he would introduce a proposed by-law change at the November Council meeting, in the duties of the nominations elections committee. Article III Section 10, reads at the moment "Nominations and Elections Committee shall nominate a slate of two persons for each of the aforementioned offices and present report to Council informational purposes." The proposed change will be to nominate a slate of one person for each of the four named offices and report to Council for informational purposes. In order to do that, the notice of intent of by-law change will have to be published in the Journal 30 days before that time. The slate will consist of one name for each office except there is a provision in that same Section for the addition of more names by petition of 25 members of the Academy. A lengthy discussion followed which included the following:

Vera Remsburg stated that she had never known a single nomination to come from the privilege of 25 members signing a petition. Gerald Taylor stated that having the two choices presented to the membership at large, to vote on, certainly makes the membership feel that they are more involved with what is occurring in the Academy... If the membership are given only one choice, they will feel they have no choice. Jim Murray stated that we nominate 2 good people for each office and one person is defeated. This tends to keep people from moving up in the Academy, it is better not to have that process of running people several times. Gerald Taylor stated that when one agrees to serve the Academy and be on the ballot, one has also agreed that they may not be elected; they may have other opportunities to be elected in the future. At the host institutions, the very fact that one has been nominated is recognition and increases the support of that institution for the Academy. Taylor also stated that he prefers at least 2 candidates on every ballot. If the membership then has someone else to propose, a 3rd candidate, that is fine but generally the membership has not done that, which, from a positive point of view, means that the membership is fairly satisfied with the quality of candidates that they have been offered in the past. Considerable discussion followed.

Motion was made by Gerald Taylor and seconded by Carolyn Conway that the statement of intent be individually mailed to each member of the Academy between now and Council meeting in November in order to determine the Academy's membership position on this. (The motion, in effect, is that each member of the Academy is sent the statement of the intent to change the by-laws and ask members whether they wish to have that change occur or to continue the current system whereby there are two candidates nominated for each office.) Discussion followed. Majority of Council wanted to consider the proposed change in by-laws over several Council meetings. **Motion called and defeated.**

Academy Motions

Michael Bass moved, seconded by Jim O'Brien, that we reappoint Blanton Bruner as Executive Secretary/Treasurer of the Academy. **Motion passed.**

Michael Bass moved, seconded by Jim O'Brien, that we re-elect or reappoint Harold Bell as the Director of the Visiting Scientist Program. **Motion passed.**

Michael Bass moved, seconded by Jim O'Brien, that we re-elect or appoint Ertle Thompson as VAS Representative to the AAAS. **Motion passed.**

Ertle Thompson noted that at the Fall Council meeting we have to reappoint the members of the Trust Committee. President Brandt stated that we need also to reappoint Vera Remsburg at that meeting.

President Brandt adjourned the Council meeting at 12:04 P.M.

Minutes recorded by G. R. Taylor, Jr., and respectfully submitted by:

Elsa Falls, Secretary
Virginia Academy of Sciences

SUMMARY OF MOTIONS

COUNCIL MEETING, FRIDAY, MAY 25, 1990

1. That Council thank George Umberger and his committee for an excellent job and that it be recorded in the minutes. Moved by Vera Remsburg, seconded by Jim O'Brien, **Motion Carried.**
2. That the statement of intent to change the bylaws, so the Nominations and Elections Committee would nominate a slate of one person for each of the four offices, be individually mailed to each member of the Academy between now and Council meeting in November in order to determine the Academy's membership position on this. Motion was made by Gerald Taylor and seconded by Carolyn Conway. Majority of Council wanted to consider the proposed change in by-laws over several Council meetings. **Motion called and defeated.**
3. That we reappoint Blanton Bruner as Executive Secretary/Treasurer of the Academy. Motion by Michael Bass, seconded by Jim O'Brien, **Motion passed.**
4. That we re-elect or reappoint Harold Bell as the Director of the Visiting Scientist Program. Motion by Michael Bass, seconded by Jim O'Brien, **Motion passed.**
5. That we re-elect or appoint Ertle Thompson as VAS Representative to the AAAS. Motion by Michael Bass, seconded by Jim O'Brien, **Motion passed.**

**VIRGINIA ACADEMY OF SCIENCE
EXECUTIVE COMMITTEE MEETING**

November 4, 1990

University of Virginia

Present: Richard Brandt (President), Gerald Taylor (President-elect), Elsa Falls (Secretary), Carolyn Conway (Treasurer), Jim Martin (Editor/Bus. Man. Journal), Carvel Blair (Guest), Dean Decker (VJAS), Blanton Bruner (Executive Secretary-Treasurer), Michael L. Bass (Immed. Past-President), Golde Holtzman (Local Arrangements Chair), Stewart Ware (Past-Past President), James O'Brien (Chair, Committee for News and Publicity), Arthur Burke (Chair, Finance and Endowment Committee)

The meeting was called to order at 10:04 a.m. by President Richard Brandt.

Approval of Executive Committee Minutes of May 23, 1990.

The minutes of the Executive Meeting of May 23, 1990, were approved as distributed, as moved by Carolyn Conway, and seconded by Stewart Ware.

President's Report by Richard Brandt.

1. The President commended Jim O'Brien on the newsletter and Jim Martin on the Journal.
2. He reported that significant progress has been made on the Annual Meeting for 1991, but there are no firm commitments after that. University of Richmond is a possibility for 1992, with William and Mary and JMU possibilities for 1993 or thereafter; the President asked Stewart Ware to report back to him within the next month on William and Mary. VCU may be possible in 1994 or 1995. Gerald Taylor indicated informal interest at VMI and Washington and Lee, combined. Dr. Brandt indicated that sites must be determined as soon as possible through 1998.
3. Vera Remsburg should be recommended for reappointment to the Science Museum of Virginia Board of Trustees at the afternoon Council meeting.
4. The new chairman of the Membership Committee is Hugo Seibel. Members of Council are automatically on the Membership Committee and are encouraged to seek new members.
5. William Banks is chair of the Nominating Committee and will prepare a slate of two persons for each office.
6. The State Education Committee of the American Cancer Society will donate \$175 a year for two years for VJAS, to be used to award first, second, and third prizes for outstanding papers related to cancer research.
7. The President distributed a rough draft of an updated VAS Directory and asked for corrections as well as suggestions for persons to be appointed to various committees. Dean Decker pointed out that committee members serve at the pleasure of the President and can be appointed for one, two, or three-year terms. It was suggested that Blanton Bruner should be an ex-officio member of the Trust Committee. Dean Decker commented that the Ad Hoc Committee on

the Future of the VJAS has completed its duties, but the President stated that he wanted the group to remain active until their recommendations have come to fruition.

Golde Holtzman suggested the formation of an Ad Hoc Committee on the Environment, which would have a reactive function; Stewart Ware pointed out that such a committee has no power on its own, but according to the Bylaws, the President and/or Council can establish such special committees. The President said he would appoint such a committee, with Carvel Blair agreeing to serve as Chair and Golde Holtzman agreeing to serve on the Committee.

8. It was pointed out that the Agricultural Science Section has not met for two years, neither at VCU and GMU. Stewart Ware indicated that the Section Chair said in 1988 the Section was going to dissolve. Golde Holtzman indicated he would like to give the Section the chance to organize at the 1991 annual meeting at VPI. The Secretary was instructed to write a letter to the last Section officers (1987-1988), asking that they give guidance to Council as to whether or not the Section should be dissolved.

9. Dr. William Banks has been appointed by the President to a three-year term as the VAS representative to the Jefferies Trust Committee.

Local Arrangements Committee Report by Golde Holtzman, Chair.

A report describing progress and plans for the annual meeting was distributed (attached). Dr. Holtzman went over a tentative schedule for the annual meeting and emphasized proposed changes from previous years, including:

1. VAS reception on Wednesday evening from 9 to 11.
2. Academy Conference on Thursday at 4:45 p.m., and Negus Lecture at 5:30 p.m.

After discussion, it was the consensus of the group that exhibitors should be open through Friday at 1 p.m., but final details on what should be provided for exhibitors and the exact times when exhibits will be opened will be worked out later.

Possible new Sections were discussed, including Computer Science, Science and Technology Studies, and Geography.

Dr. Holtzman indicated there is the possibility that a package deal might be forthcoming for campus accommodations for VAS members for the annual meeting. Gerald Taylor cautioned that the meeting has to break even. Blanton Bruner estimated that \$4500 to \$5000 has to be returned to VAS by the host institution to insure the Academy does break even.

President-Elect's Report by Gerald Taylor.

1. Dr. Holtzman is doing an excellent job on the annual meeting. Positive changes and highlights of that meeting include: all Section business meetings will be at 11:30 a.m. on Thursday; all Section papers end at 4:30 p.m. on Thursday, with the Academy Conference to follow at 4:45, at which time section representatives will introduce new officers; the Negus Lecture will be a multi-media presentation by Paul Knappenberger (no honorarium involved, but \$200 will be provided by VAS to cover presentation costs.)

2. A proposed Computer Science Section will meet for the first time at the 1991 annual meeting.

3. At the Council meeting he will propose the establishment of a \$300 travel fund for the VAS representative to the Science Museum of Virginia Board, and a President's discretionary fund of \$500.

4. Dr. Taylor distributed a schedule of responsibilities for the annual meeting (attached). It was noted that titles of papers are to be sent to him as well as to the section secretaries so that he will know what is going on and so that the program can be planned in a knowledgeable fashion. Although this change might lead to confusion, the consensus was that this method should be tried and if it works, it should become standard procedure.

Dr. Taylor stated that membership applications should be modified to include telephone numbers and electronic mail information.

He noted that the first call for papers will be the first week in January, as well as the call for nominations from the Chair of the Nominating Committee.

5. Dr. Taylor is donating the software package Quatro-Pro to the Academy office.

In view of the length of the meeting, other reports were postponed until the afternoon Council meeting; the meeting was adjourned, upon motion by Carolyn Conway and second by Gerald Taylor, at 12:25 p.m.

Respectfully submitted by:

Elsa Q. Falls, Secretary

Virginia Academy of Science

**VIRGINIA ACADEMY OF SCIENCE
COUNCIL MEETING**

November 4, 1990

University of Virginia

Present: Richard Brandt (President), Gerald Taylor, Jr. (President-Elect), Elsa Falls (Secretary), Rosemary Barra (Biology Section Councilor), James O'Brien (Chair, Committee for News and Publicity & Psychology Section Councilor), J. Mark Wittkofski (guest and member of Virginia Archaeologists), Carolyn Conway (Treasurer), Stewart Ware (Past-past President), Art Burke (Past-past-past-past President & Chair of Finance and Endowment Committee), Blanton Bruner (Executive Secretary-Treasurer), C. Roy Taylor, Jr. (Chair, Fund Raising Committee), Dean Decker (Director, VJAS), Jim Martin (Editor/*Bus. Man. Journal*), Michael L. Bass (Immediate Past President), Vera B. Remsburg (Rep. to Science Museum of Va. Board), Ertle Thompson (AAAS Rep. & Chair of Science Educ.), Lisa T. Alty (Medical Science Section Councilor), Carvel Blair (Environmental Sciences Councilor), Jim Murray (Chair, Awards Committee), Harold Bell (Director, Visiting Scientists Program), Rae Carpenter (Chair, Trust Committee), Golde Holtzman (Chair, Local Arrangements), Tom Sitz (Chair, Research Committee), Martha Roane (Chair, Archive Committee and Virginia Flora Committee).

The meeting was called to order at 1:20 p.m. by President Richard Brandt.

Approval of Council Minutes of May 23 & 25, 1990.

The minutes of May 23, 1990, and May 25, 1990, were approved with minor corrections, as moved by Carolyn Conway and seconded by Roy Taylor.

President's Report by Richard Brandt.

1. The President commended Jim O'Brien on the newsletter and Jim Martin on the *Journal*.
2. He stated that the 1991 annual meeting would be held at VPI; the schedule after that is uncertain, but he would like to schedule meetings through 1998 as soon as possible.
3. He announced that the State Education Committee of the American Cancer Society will donate \$175 a year for two years to VJAS, to be used to award first, second, and third prizes for outstanding papers related to cancer research.
4. A rough draft of an updated VAS Directory was distributed, and the President asked for corrections and suggestions for committee members. He commented that there has been some improvement in representation of women on Council, but there is no minority representation; role models are needed for students, and suggestions would be welcomed.
5. Dr. William Banks has been appointed by the President to a three-year term as the VAS representative to the Jefferies Trust Committee.
6. Blanton Bruner announced a bequest of \$1000 from the estate of Dr. George William Jeffers.

Report of Immediate Past President, Michael Bass.

1. He stated that he is serving as VAS representative and advisory member to a state committee which is submitting an NSF grant proposal to promote education in mathematics and science in Virginia, particularly for minorities. Two million dollars is being requested for each of five years, and VAS is being listed as one of the partners to the state, to help direct funds.

2. Dr. Bass reminded the group that Vera Remsburg must be renominated to the Science Museum of Virginia Board of Trustees, since her first term ends on June 30, 1991. One member of the Board of Trustees must be a member of VAS, and that person is proposed by VAS and appointed by the Governor. The motion, as moved by Gerald Taylor and seconded by Ertle Thompson, that Vera Remsburg be nominated for a second five-year term as VAS representative to the Science Museum of Virginia Board of Trustees was passed unanimously. Elsa Falls was requested to draft a letter indicating our nominee to be sent to Paul Knappenberger and the Governor of Virginia.

Local Arrangements Committee Report by Golde Holtzman, Chair.

A tentative VJAS and VAS General Program Schedule for the 1991 annual meeting was distributed (attached). Dr. Holtzman noted certain changes, including: VAS reception will be held from 9-11 p.m. on Wednesday and the Academy Conference will be held at 4:45 p.m. on Thursday, with the Negus Lecture to follow at 5:30. Ertle Thompson commended the Committee for the schedule changes, hoping that it would improve attendance at the Conference and Lecture.

President-Elect's Report by Gerald Taylor.

1. Dr. Holtzman is doing an excellent job. The structure of the annual meeting will be changed so that every section business meeting will be held at 11:30 a.m. on Thursday and all section paper sessions will end at 4:30 on Thursday; at 4:45 section representatives or chairs will be asked to present their new officers at the Academy Conference. The Negus Lecture will follow at 5:30, and the banquet will be from 8 to 10 p.m.

2. A proposed Computer Science Section will meet for the first time at the 1991 annual meeting.

3. Dr. Taylor moved that, for action at the March 1991 meeting of Council, the Constitution and Bylaws Committee, Frank Leftwich, Chair, recommend appropriate changes in Article VII: Official Representation of the Academy (and other articles or bylaws as required), to allow Council to permanently establish a \$500 President's Discretionary Fund (which can also be used for personal expenses or travel in official representation of the Academy) and to establish a \$300 Science Museum of Virginia Representative Travel Fund, subject to availability of funds in the budget. An annual summary report on use of these funds is to be presented to the Executive Committee for accounting purposes. The motion was seconded by Michael Bass and unanimously passed.

Secretary's Report by Elsa Falls.

The secretary requested that anyone making motions or presenting reports to Council submit a copy to her in writing.

Treasurer's Report by Carolyn Conway. No report.Executive Secretary-Treasurer's Report by Blanton Bruner.

Dr. Bruner reported that the proposed budget for 1991 had been prepared and would be presented later in the meeting by Arthur Burke, Chair of the Finance and Endowment Committee and that bills for dues would be mailed to members next week.

Virginia Academy of Science Report by Dean Decker.

1. Dr. Decker reported that there were no VJAS poster sessions, as had been planned, at the State Fair in September, because the individual in charge of the project at the Fair left the position; the future status is unknown.
2. Plans for the 50th Anniversary Celebration for the VJAS are progressing.
3. He attended South Carolina Junior Academy meetings and was impressed at the strong state university and college support in the way of workshops for Junior Academy students.

Virginia Journal of Science Report by Jim Martin, Editor.

One issue is in the mail now; the next will go out in January. Please encourage people to submit papers.

Report by Director of Visiting Scientists Program by Harold Bell.

Dr. Bell's report (attached) included the following: 1) The 1990-1991 speakers list (attached) was mailed to high schools and community colleges this fall, and 200 extra copies will be distributed at the November 9 meeting of high school science teachers in Charlottesville. 2) The Report-of-Visit form is not being used. 3) Costs have been held to a minimum. 4) Shouldn't we conduct an evaluation of the program?

Gerald Taylor suggested the Academy should think about creating an electronic bulletin board; the visiting scientists program could be on it.

The problem of insuring that teachers get the program was discussed. Jim O'Brien suggested mailing the program to advisors of VJAS clubs, which Dr. Bell agreed to do.

AAAS Report by Ertle Thompson, AAAS Representative.

He reported that the program has been completed for the AAAS meeting in February in Washington, D.C. and urged members to attend.

Archives Report by Martha Roane.

She urged members to send archival material to Glen McMullen at the Newman Library, VPI.

Awards Committee Report by Jim Murray.

The Committee has two nominations for Fellows and one for a Distinguished Service Award; these nominations will be made at the next Council meeting.

Constitution and By-Laws Committee. No report.Committee on Science Education Report by Ertle Thompson.

Dr. Thompson has worked with Dr. Joe Exline of the Virginia Department of Education to develop plans for VAS responsibilities for the November 9 meeting of high school science teachers in Charlottesville.

Report of Finance and Endowment Committee by Arthur Burke.

A proposed budget for 1991 was distributed (attached). Dr. Burke pointed out that the annual budget has to be developed for the next year before the figures for the current year are in, and this is always a problem. The decline in membership in the VAS has been compensated for by increases in the VJAS. It was noted that projected deficits would be off-set by reserve funds. Dean Decker indicated that some corporate support is promised for the 50th Anniversary of VJAS, which will help. Martha Roane asked where the money would come from for the President's discretionary fund and travel fund for Science of Museum Board representative; Dean Decker reminded the Council those funds cannot be allocated without the proposed change in by-laws. By the March Council meeting Arthur Burke commented that our financial situation will be clearer, and Council may wish to make some changes in the proposed budget. Blanton Bruner indicated that VAS has not received any funds from GMU from the 1990 annual meeting, but those monies should be forthcoming shortly and in the range of \$10,000, according to Local Arrangements Chair Dr. Umberger. Dr. Bruner commented that the Academy's financial situation is always at the lowest point in September and October, and we are no worse off than in previous years. Arthur Burke stated that VAS has slightly over one year's operating expenses in reserve.

As moved by Arthur Burke for his committee, the proposed budget for 1991 was adopted.

Fund Raising Committee Report by Dean Decker.

Breakfasts were held with community and corporate leaders last spring as part of the feasibility study, with about half of those invited showing up. Not much has happened since then because two committee members have changed positions. A report should be available for the March Council meeting. Roy Taylor indicated that development of a brochure for the campaign will be a primary objective for the near future.

It was moved by Gerald Taylor and seconded by Jim O'Brien that the Committee be authorized to continue planning in order to be ready to seek funds in conjunction with the 50th Anniversary Celebration of the VJAS; sufficient funds should be sought to regionalize the VJAS, to hire a full-time director for VJAS-VAS, and to operate the office. The motion was approved.

Stewart Ware reminded the Council that it would have to decide whether to proceed with these plans when the final written report is presented by the Fund Raising Committee.

Responding to a question by Stewart Ware, Dean Decker said we do not know whether regionalization will decrease attendance at the annual VJAS meeting; some institutions cannot handle the number who attend now. Arthur Burke cautioned that we must not end up going only to three or four large universities because that will be a disincentive for small colleges to attend.

Nominations Committee Report by the President for William Banks.

The Committee will prepare a slate of two nominees for each office.

Membership Committee Report by the President for Hugo Seibel.

Letters are being sent to all pre-med advisors asking them to serve as recruiters for the Academy. There will be an appeal in the newsletter, and a letter will be drafted to each science department chair in institutions of higher learning to inform them of the Academy. Dr. Seibel proposes that Council consider making the first year of membership free for graduate students.

Research Committee Report by Tom Sitz.

He received six proposals for Horsley Grants; five were from people at VPI. The Committee is interested in people at other institutions applying also. Horsley Grant proposals are reviewed in the fall and small project research grant proposals are reviewed in the spring.

Science Advisory Committee Report by Ertle Thompson.

Dr. Thompson reviewed a decade of history of the role and evolution of the Science Advisory Committee (Report of history through 1978 attached). The Commonwealth has in recent years sought little input from VAS through this committee. The President requested that the history be put in writing so that in the future VAS can have access to it.

Trust Committee Report by Rae Carpenter.

Dr. Carpenter submitted a report (attached) listing the current holdings in all Academy funds showing cost basis, recent price, Dec. 89 audit value and sales of securities in 1990. The total worth for all funds as of October 30, 1990 is \$140,108; this is down approximately \$17,500 from the value on July 20, 1990. This trend follows that of the stock market which has been mostly downhill since the Gulf crisis, but, comparatively speaking, VAS investments have suffered an average loss of 12% while the Dow Jones Industrial Average has declined about 17%.

Report of Virginia Flora Committee by Martha Roane.

Funds for this year have been distributed equally between Michael Hill at Bridgewater and Miles Johnson at VCU.

Report of News and Publicity Committee by James O'Brien.

A written report was distributed (attached) in which Dr. O'Brien listed a number of needs which, if addressed, would lead to improvement of the newsletter. He requested that committee chairs write articles for the newsletter regarding issues of which the membership should be informed. It was stressed that rapid turnaround is necessary when input is sought by him regarding newsletter drafts from Academy officers. He requested suggestions relative to who should receive complimentary copies of the newsletter (Virginia Scientists) in order to increase visibility of the Academy. Carolyn Conway suggested sending it to science department chairs. Arthur Burke suggested that Dr. O'Brien bring a revised budget to the March meeting as it sounds like the proposed budget may not cover mailing costs for the newsletter. It was suggested that Council should consider making this a standing committee.

Report by Representative to the Science Museum of Virginia, Vera Remsburg.

Exhibits are currently being developed on the life sciences and railroads at the Museum. The Museum has recently taken over the Air Museum of Virginia. There are now two mobile units which are traveling around the State. The "Science By Mail" program is going well. In order to comply with Governor Wilder's feeling that the Science Museum should get out all over the state, the Trustees will be meeting in various locations. The Attorney General has approved locating the VAS office in the Museum, whenever the Academy so desires; fees in payment for having the office there would be token in amount.

Medical Science Section Report by Lisa Alty. No report.Old Business.

It was moved by Vera Remsburg and seconded by James O'Brien that a fund be established within the VJAS endowment to honor the memory of Dr. George William Jeffers, and that the income be used to support at least in part a memorial George W. Jeffers VJAS lecture. The motion passed unanimously. Initial contributions to the fund will include \$1000 from the estate of Dr. Jeffers and \$1000 from a private donor.

It was moved by James Murray and seconded by Arthur Burke that the Chairman of the Constitution and Bylaws Committee bring to the next Council meeting a proposal to amend the Constitution and Bylaws in order to modify the procedure for nominating Academy officers so that only one person would be nominated by the Nominating Committee for each position and so that nomination by petition would require ten names.

An amendment was proposed by Golde Holtzman and seconded by James O'Brien, that the number of names required for petition be left as it now is in the Bylaws, at 25 names. The amendment was approved.

The motion, as amended, was approved.

New Business.

James O'Brien introduced J. Mark Wittkofski, who was representing Virginia Archaeologists, a group interested in presenting papers at the 1991 Annual Meeting and ultimately becoming a Section of VAS. Dr. Wittkofski is willing to serve as program chair for the proposed Section until a business meeting can be held to elect officers.

It was moved by Rae Carpenter and seconded by James O'Brien that the archaeologists be granted permission to organize and hold their first meeting at the Academy 1991 Annual Meeting at VPI, in order to initiate the process necessary to become an official VAS Section. The motion was approved.

It was moved by Gerald Taylor and seconded by James O'Brien that computer science be granted permission to organize and hold its first meeting at the Academy 1991 Annual Meeting at VPI, in order to initiate the process necessary to become an official VAS Section. The motion was approved.

Gerald Taylor will serve as organizer for the computer science group.

President Brandt adjourned the meeting at 5:35 p.m.

Respectfully submitted by:

Elsa Q. Falls, Secretary

Virginia Academy of Science

SUMMARY OF MOTIONS**COUNCIL MEETING, SUNDAY, NOVEMBER 4, 1990**

1. That the minutes of May 23, 1990, and May 25, 1990, be approved with minor corrections. Moved by Carolyn Conway and seconded by Roy Taylor. **Motion passed.**

2. That Vera Remsburg be nominated for a second five-year term as VAS representative to the Science Museum of Virginia Board of Trustees. Moved by Gerald Taylor and seconded by Ertle Thompson. **Motion passed unanimously.**

3. That, for action at the March 1991 meeting of Council, the Constitution and Bylaws Committee, Frank Leftwich, Chair, recommend appropriate changes in Article VII: Official Representation of the Academy (and other articles or bylaws as required), to allow Council to permanently establish a \$500 President's Discretionary Fund (which can also be used for personal expenses or travel in official representation of the Academy) and to establish a \$300 Science Museum of Virginia Representative Travel Fund, subject to availability of funds in the budget. An annual summary report on use of these funds is to be presented to the Executive Committee for accounting purposes. Moved by Gerald Taylor and seconded by Michael Bass. **Motion passed unanimously.**

4. That the proposed budget for 1991 be adopted. Moved by Arthur Burke for his committee. **Motion passed.**

5. That the Fund Raising Committee be authorized to continue planning in order to be ready to seek funds in conjunction with the 50th Anniversary Celebration of the VJAS; sufficient funds should be sought to regionalize the VJAS, to hire a full-time director for VJAS-VAS, and to operate the office. Moved by Gerald Taylor and seconded by Jim O'Brien. **Motion passed.**

6. That a fund be established within the VJAS endowment to honor the memory of Dr. George William Jeffers, and that the income be used to support at least in part a memorial George W. Jeffers VJAS lecture. Moved by Vera Remsburg and seconded by James O'Brien. **Motion passed unanimously.**

7. That the Chairman of the Constitution and Bylaws Committee bring to the next Council meeting a proposal to amend the Constitution and Bylaws in order to modify the procedure for nominating Academy officers so that only one person would be nominated by the Nominating Committee for each position and so that nomination by petition would require ten names. Moved by James Murray and seconded by Arthur Burke.

Amendment proposed that the number of names required for petition be left as it now is in the Bylaws, at 25 names. Moved by Golde Holtzman and seconded by James O'Brien. **Motion, as amended, was approved.**

8. That the archaeologists be granted permission to organize and hold their first meeting at the Academy 1991 Annual Meeting at VPI, in order to initiate the process necessary to become an official VAS Section. Moved by Rae Carpenter and seconded by James O'Brien. **Motion was approved.**

9. That computer scientists be granted permission to organize and hold their first meeting at the Academy 1991 Annual Meeting at VPI, in order to initiate the process necessary to become an official VAS Section. Moved by Gerald Taylor and seconded by James O'Brien. **Motion was approved.**

JEFFRESS RESEARCH GRANT AWARDS

The Allocations Committee of the Thomas F. and Kate Miller Jeffress Memorial Trust has announced the award of Jeffress Research Grants to the institutions listed below to support the research of the investigator whose name is given. The Jeffress Trust, established in 1981 under the will of Robert M. Jeffress, a business executive and philanthropist of Richmond, supports research in chemical, medical and other natural sciences through grants to non-profit research and educational institutions in the Commonwealth of Virginia. The Jeffress Research Grants being announced here have been awarded in 1990.

The Jeffress Memorial Trust is administered by Sovran Bank, N.A. Additional information about the program of the Trust may be obtained by writing to: Advisor, Thomas F. and Kate Miller Jeffress Memorial Trust, Trust Department, Sovran Bank, N.A., P.O. Box 26903, Richmond, VA 23261.

Mark R. Anderson, Virginia Polytechnic Institute and State University. *In situ* characterization of the structure and charge transfer properties of self-assembled monolayer films. \$31,450 (one year).

Patrick K. Bender, Virginia Polytechnic Institute and State University. Determinants of gamma subunit interactions with calmodulin. \$46,114 (three years).

Carol N. Boozer, Eastern Virginia Medical School. Fuel oxidation and diet-induced obesity. \$41,450 (two years).

Clive Bradbeer, University of Virginia. Studies on intracellular cobalamin transport processes. \$25,663 (one year).

Anthony D. Carter, Virginia Commonwealth University. G-protein dependent regulation of metallothionein gene transcription: implications for inherited diseases of ion transport. \$50,803 (three years).

Fu-lin Chu, Virginia Institute of Marine Science. Immune capacity and susceptibility of eastern oysters, *Crassostrea virginica*, to the pathogen, *Perkinsus marinus*. \$17,163 (one year).

David L. Cull, Eastern Virginia Medical School. Influence of monocyte pre-seeding on the kinetics of endothelial cell seeding of canine prosthetic arterial grafts. \$15,904 (one year).

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**Abstracts of Papers Presented at the
Sixty-ninth Annual Meeting, Virginia Academy of Science
May 21-24, 1991, Virginia Polytechnic Institute and State University,
Blacksburg, VA**

Aeronautical and Aerospace Sciences

F-18 HIGH ANGLE-OF-ATTACK AERODYNAMICS. Daniel W. Banks, NASA Langley Research Center, Hampton, VA 23665-5225. In order to be more maneuverable, fighter aircraft have the need to operate at high angles of attack. During these high angle-of-attack or post-stall operations, the flow field around the aircraft behaves differently than during conventional flight operations. Aircraft components other than the wing, in particular the forebody, become crucial in determining the overall aerodynamics. This in turn dictates the stability and control of the aircraft and can lead to adverse phenomena such as tail buffet and wing rock. By properly understanding the physics of these flow fields, these adverse phenomena can be solved more readily and future aircraft can be designed more effectively. This paper will present results from wind tunnel and flight tests of the NASA F-18 High-Alpha Research Vehicle (HARV). The F-18 configuration was chosen because of its interesting high-angle-of-attack characteristics, its unrestricted operational angle-of-attack envelope (within weight and center of gravity limits), and the availability of a flight test aircraft and wind tunnel models.

GENERIC HYPERSONIC INLET MODULE ANALYSIS. Charles E. Cockrell, Jr. NASA Langley Research Center, Mail Stop 413, Hampton, Va. 23665-5225. Hypersonic air-breathing aircraft, such as the National Aerospace Plane (NASP) rely on body-mounted, supersonic combustion ramjet (SCRAMJET) propulsion systems. A characteristic of such a design is that the propulsion system must be highly integrated with the airframe, with the entire underside of the aircraft functioning as part of the propulsion system. One issue related to propulsion/airframe integration is the calculation of aerodynamic forces and moments for each engine component. Additionally, it is anticipated that the design of such a vehicle will rely heavily on computational fluid dynamics (CFD), due to the inability of ground test facilities to model all aspects of the full-scale configuration. In the present study, a computational analysis and an internal inlet drag analysis were performed for a generic hypersonic inlet module. The configuration studied models aspects of forebody and inlet flows seen in designs for body-mounted scramjet engines. Viscous and inviscid CFD solutions were obtained for the inlet flow field with solution accuracy assessed by comparison with experimental data. Internal drag force predictions were calculated based on CFD solutions and experimental data with a comparative assessment made of each approach. The results indicate the feasibility of obtaining drag force values computationally, assess the sensitivity of CFD drag predictions to computational methods, and resolve issues relating to the computation of this type of hypersonic flow field.

BRIDGING THE GAP BETWEEN CONCEPTUAL AND PRELIMINARY DESIGN. S. Jayaram*, Mechanical Engineering Department, Va. Polytechnic Inst. & State Univ., Va. 24061. Computer aided design systems are available for all stages of the aircraft design process – from conceptual design (sizing programs) to detailed final design (final design CAD/CAM systems). Since 1987, the Computer Aided Design Laboratory at Virginia Tech. has been enhancing a well-known aircraft conceptual design system called ACSYNT (AirCraft SYNthesis). ACSYNT is a device-independent, interactive CAD system for parametric aircraft design. This research and development effort has been undertaken in cooperation with NASA-Ames. In 1990, the "ACSYNT Institute" was formed to support this research program. Current members of the ACSYNT Institute include NASA-Lewis, NASA-Langley, U.S. Air Force Academy, China Lake Naval Weapons Center, Lockheed, Northrop, Boeing, G.E. Aircraft Engines, McDonnell Douglas and Defense Group Inc. ACSYNT allows the designer to create aircraft geometry by specifying shape and size parameters for the components (e.g. span, sweep, fineness ratio, etc.). Recent research has concentrated on the creation of curvature continuous surface models of these designs for use in preliminary design systems (e.g. CFD). Research is also being conducted in analyzing surface data generated by preliminary design systems and automatically obtaining the shape parameters for the aircraft components. This presentation describes these research efforts and highlights some of the problems encountered in the attempt to automate the transfer of geometry data between conceptual and preliminary design systems.

AN EVALUATION OF THREE WING PLANFORMS FOR USE ON A SUPERSONIC TRANSPORT. Glenn L. Martin, Lockheed Engineering & Sciences Company, Hampton, Va. 23666. In the past, many different wing planforms have been studied for use in supersonic flight; however, rarely were they compared in a systematic manner using a specific set of ground rules. A study was conducted to evaluate three wing planforms - trapezoidal, "M", and arrow - for use on a supersonic transport sized to perform a 5500 nautical mile mission with a payload of 250 passengers at a Mach number of 2.0. Geometrically similar trapezoidal and "M" wings on generic bodies were compared to determine the relative merits of each. Further analyses identified wing geometries for these two planforms which satisfied the aerodynamic requirements. The arrow wing geometry was based on recent High Speed Civil Transport studies. Realistic supersonic transport configurations were then developed using the three planforms. From the results of the study, the advantages/disadvantages of each of the concepts were identified in the areas of packaging, aerodynamics, and structures.

FIVE DECADES OF AEROSPACE RESEARCH. M. Leroy Spearman, NASA Langley Research Center, Hampton, Virginia 23665-5225. This being the 50th anniversary of the Virginia Junior Academy of Science it is appropriate to review five decades of aerospace research, particularly as related to the Langley Research Center of NASA and its predecessor NACA. In the early 1940's, airplanes were propeller driven and were generally limited to a top speed of about 400 m.p.h. In the mid-1940's, jet propulsion for airplanes became a reality and the top speeds began to approach 600-700 m.p.h. New shapes began to appear to accommodate the higher speeds and, by 1950, rocket propelled airplanes had broken the transonic sound barrier and supersonic flight had been achieved. During the 1960's, hypersonic flight was achieved with the X-15 and the first flights into space were made - suborbital and orbital, both unmanned and manned. In the 1970's and 1980's many new airplane designs appeared and the space shuttle first flew. Current research is directed toward various advanced systems that include supersonic civil airplanes and hypersonic research airplanes. Many dramatic changes in aerospace research have occurred over the past five decades and only time will tell what changes lie ahead.

THE NASA HIGH-SPEED RESEARCH PROGRAM. Matthew M. Winston,* Langley Research Center, Hampton, Va. 23665-5225. The High-Speed Civil Transport (HSCT), a proposed new generation of supersonic passenger airplane must be environmentally acceptable in terms of community noise, atmospheric pollution, and sonic boom. It must also offer operational economics sufficient to capture a significant segment of the long-range travel market. The NASA High-Speed Research Program is aimed toward finding solutions to the barrier environmental problems and providing the necessary economic enhancements through advanced disciplinary and systems-level research and technology. The first phase of the program is focused on the environment and includes efforts to: (1) predict the effects of engine emissions on stratospheric ozone; (2) determine the feasibility of reducing the production of harmful emissions through engine combustor design; (3) reduce noise to comply with existing regulations; and (4) to predict and reduce the annoyance of sonic booms. Later phases will focus on design considerations for economic enhancement such as advanced materials and structural concepts, advanced propulsion systems, improved high-lift and cruise aerodynamics, and new cockpit and flight management technology. Together with NASA, contributions to this effort are being made by many persons in the airframe and aircraft engine industries, the atmospheric sciences community, the materials industry, and academia.

Agricultural Sciences (*Business Meeting Only*)**Archaeology**

PALEO-ETHNOZOOLOGY IN VIRGINIA: HISTORY, RESEARCH POTENTIAL, AND CONTRIBUTIONS. Michael B. Barber, Jefferson National Forest, Roanoke, Va. 24001. The analysis of archaeologically recovered animal bone has an unfortunately short history within the Commonwealth. Although the interest in archaeology and paleontology per se has roots in the Jeffersonian era, the scientific analysis of faunal material for the purpose of obtaining anthropological insight has only a brief history of 20± years. Although it could be argued that the laundry list approach of the 1950s and 1960s offered some information into the distribution of paleo-fauna and prehistoric utilization patterns, it lacked the appropriate anthropological underpinnings which lead to a better understanding of culture process. A compendium of research potentials of the scientific study of faunal material is presented as well as a history of the discipline in Virginia.

PALEOETHNOBOTANY: ANOTHER FACET TO A MULTIDISCIPLINARY ARCHAEOLOGY. Eugene B. Barfield, Jefferson National Forest, Roanoke, Virginia 24001. Although study of plant remains from archaeological sites began in the 19th Century, it wasn't until the 1930's that real interest occurred in the United States. As the basic tenet of archaeology is attempting reconstruction of the dynamics of past cultural systems, knowledge of subsistence practices, through time, are invaluable indicators in helping define social complexity. This paper will trace paleoethnobotanical evidence across the country into Virginia and discuss cultivation, horticulture and spin-offs and effects of horticulture and domestication on social organization in Virginia prehistory.

MOTHER WHO? ENVIRONMENTAL DEGRADATION OF THE NEW WORLD; PALEO, ARCHAIC AND WOODLAND PERIODS. Lori Barfield, Jefferson National Forest, Dept. of Geog., Radford Univ., Radford, Va. 24142. The earliest human occupants of North America degraded their environment in much the same way as do the present inhabitants. At least in part, aboriginal activities were responsible for the extinction of species and significant modification of their environments. Aboriginal populations were continually forced to adapt to the changed environments which they had created. Of necessity, early North American populations changed their subsistence patterns either as a result of depletion of a food source, population pressure, or development of a market economy. When a resource was plentiful enough that population needs were met by reserves in the environment, little thought was given to conservation. When resources were limited through overuse then aboriginals either adapted themselves and/or their environment to new regimes.

THE REWORKING OF ANGLO-ELEMENTS IN AFRICAN PATTERNS ON AMERICAN SOIL: UNDERSTANDING AFRICAN ADAPTATION TO THE PLANTATION SYSTEM. Alison Bell, Dept. of Anthro., Washington & Lee University, Lexington, VA 24450. In examining studies on African-American music, religion and language, the same pattern consistently surfaces: slaves appropriated elements of Anglo-American culture and reinterpreted them according to Old World perceptions. They adopted English words into west African sentence structures, selected parts of Christianity and shaped them to accommodate African religious traditions, and accepted Anglo-American music only to transform it into ancestral forms. The African influence evident in non-material slave culture includes an intensely communal ethic and unification of secular/religious, public/private. These values are apparent in extant African-American material culture, with manifestations ranging from architecture to quilting designs. No reason exists to assume that this method of cultural syncretism and pattern of reworking does not also extend to the archaeological record. The challenge is in learning to recognize it.

ETHNOHISTORIC AND ARCHAEOLOGICAL INTERPRETATIONS OF DESOTO AND JUAN PARDO'S ROUTES. C. Clifford Boyd, Jr., Dept. of Sociology and Anthropology, Radford Univ., Radford, Va. 24142. The expeditions by Hernando de Soto and Juan Pardo into the southeastern portion of North America in the mid-1500s A.D. are some of the best documented early European explorations of this region. This paper evaluates the accuracy of the ethnohistoric documentation and its use in reconstructing the routes of these *entradas*. Archaeological evidence, in the form of European trade items and other artifacts and their distribution, are also evaluated for what they reveal about the expeditions and the Native American cultures they encountered. Finally, an anthropological perspective is presented for the interpretation of these events.

BIOLOGICAL RELATIONSHIPS OF LATE PREHISTORIC SOCIETIES IN MIDDLE AND EAST TENNESSEE. Donna C. Boyd, Dept. of Sociology and Anthropology, Radford Univ., Radford, Va. 24142. Relationships among three late prehistoric (A.D. 1300-1600) Tennessee societies are reexamined using current biological data from six archaeological sites representing these roughly contemporaneous cultures. Past research has indicated possible close associations between two of these cultures--Mouse Creek and Middle Cumberland--to the exclusion of the third, Dallas. However, more recent and thorough analysis of skeletal remains from these cultures contradicts previous conclusions regarding interrelations among these groups. Multivariate analyses of craniofacial and mandibular dimensions of individuals from these cultures indicates a closer biological relationship between Mouse Creek and Dallas. More recent archaeological and ethnohistoric data from these six sites support these findings.

A TALE OF TWO TAVERNS: A COMPARATIVE ECONOMIC ANALYSIS OF THE WETHERBURN AND SHIELDS TAVERNS. Tanja M. Dickinson, New Horizons Tech. Center, Hampton, Va. 23666. Two excavated tavern sites from the middle of the 18th century in Colonial Williamsburg, Va. were studied to determine the differences in the two taverns in terms of clientele, quality of accommodations, and equipment used. This was accomplished by researching the time, area, and various taverns of the 18th century. Research on various artifacts and artifact identification was also necessary for the comparison of the two establishments. Upon analysis, it is expected that the Wetherburn Tavern was frequented by persons of a higher social and economic status, while Shields catered more to the middle class.

LINKING ARCHEOLOGICAL CULTURES WITH HISTORIC INDIAN GROUPS. Howard A MacCord, Richmond, Va. Assuming cultural conservatism and lacking evidence of movement, we can with confidence trace Indian groups found in Virginia in 1607 back into prehistory, and in some cases as far back as AD 1400. Primary evidence is in ceramics, house and village types, burial traits, and continuity in toolkit technology, materials and styles. Best evidence applies to groups east of the Blue Ridge. For the Patowomeke group, we can demonstrate a migration from the Potomac Piedmont area to the tidewater Potomac around AD 1450. For areas west of the Blue Ridge, late prehistoric cultures are well defined, but no tribal groups are known. Conclusions are based on recent and on-going fieldwork.

ECONOMIC CHANGE AT AN EIGHTEENTH CENTURY PLANTATION. Scott K. Parker and Lynne G. Lewis, Montpelier Res. Ctr., National Trust for Historic Preservation, Montpelier Station, VA 22957. Montpelier, the life-long home of President James Madison in Orange County, Virginia, presents a unique opportunity to study the broad span of Virginia history from the earliest human occupation through the present. Most recently, archaeological research has concentrated on the Madison period of ownership. The plantation was managed by three generations of Madisons, each with its own distinct economic focus. The implications of this will be discussed, with particular emphasis on James Madison, Sr.'s activities as recently revealed through archaeological and documentary research. Of special interest is the shift in the mid-18th century from a tobacco-based to a multi-faceted, entrepreneurial economy. The discovery of a major ironworking industry, operated by African American slaves, as well as other business activities, has shed new light on the understanding of 18th century Piedmont plantation life.

POLLEN, PARASITES, AND PRIVIES: AN ANALYSIS OF AN EARLY EIGHTEENTH-CENTURY PRIVY IN WILLIAMSBURG. Patricia M. Samford, Department of Archaeological Research, Colonial Williamsburg Foundation, Williamsburg, Va. 23187. Recent excavations at Colonial Williamsburg revealed the remains of a privy built, used, and destroyed between 1717 and 1727. In addition to containing household and gunsmithing artifacts from resident John Brush, the privy also revealed large quantities of seeds, pollen, and human parasite egg sacs. The analysis of this material provides information on diet, health, and landscape reconstruction in early eighteenth-century Virginia.

PREHISTORIC ARCHAEOLOGICAL RECORDS OF THE ROANOKE BASS (AMBLOPLITES CAVIFRONS) IN VIRGINIA. Thomas R. Whyte, Dept. of Anthropology, Appalachian State Univ., Boone, NC 28608. The Roanoke bass (Ambloplites cavifrons), once widespread in the Roanoke, Tar, and Neuse River drainages of Virginia and North Carolina, is now rare and, in the Roanoke drainage, nearly extirpated. Archaeological remains of this fish from four late prehistoric sites in Virginia indicate that the species was once more common and widespread and was an important food fish for prehistoric Native Americans residing along the Roanoke River.

THE LATE UNPLEASANTNESS: AN EXAMINATION OF THE ARCHAEOLOGICAL INVENTORY OF CIVIL WAR SITES IN VIRGINIA. J. Mark Wittkofski, Virginia Department of Historic Resources, Richmond, Va. 23219. Until recently, archaeologists have not paid much attention to Civil War archaeological sites. Threats of destruction to these endangered properties have brought about studies by archaeologists throughout the Commonwealth. The Department of Historic Resources has helped lead the effort to protect and preserve the more significant Civil War properties in the state. As part of its program of survey and planning, an assessment was made of the official archaeological inventory of 21,000+ sites to determine the number, type, and nature of Civil War archaeological sites recorded in the files. Presented here, is a brief analysis of this assessment and suggestions for additional research.

Astronomy, Mathematics, and Physics

Efficiency of Blackbody Lamp-Pumped Nd:YAG Laser.¹ Donica Allen* and In H. Hwang*, Dept. of Physics, Hampton Univ., Hampton, Va. 23668. A blackbody pumped Nd:YAG laser system was modeled to determine the optimum pumping condition for the laser system. The efficiency was determined for several blackbody lamp temperatures for three laser materials. Analysis showed the optimum temperature to be about 6000 K for optimum efficiency of the laser system for each material.

1. Work is supported by NASA grant No. NAG 1-1091

DRIFT CHAMBER PERFORMANCE IN A MEDIUM ENERGY PION BEAM. O. K. Baker, R. Carlini*, S. Christo*, B. Kross*, D. Mack*, S. Majewski*, G. Malamud*, A. McCauley*, W. Naing, J. Napolitano*, R. Raney*, A. Weisenberger*, and S. Wood*, Physics Department, Hampton University, Hampton, VA 23668, and Continuous Electron Beam Accelerator Facility, Newport News, VA 23606. Drift chambers are the most commonly used devices for tracking charged particles in intermediate energy nuclear physics experiments. A variety of these chambers will be used at the Continuous Electron Beam Accelerator Facility (CEBAF) for determining charged particle trajectories in electron scattering experiments. We have constructed a prototype of the multiwire drift chambers to be used in the High Momentum Spectrometer (HMS) at CEBAF. This prototype chamber was recently tested in a medium energy (≈ 150 MeV) pion beam with impressive results. An overview of the experimental setup and procedures as well as highlights of the chamber performance will be presented.

THE CONCEPTUAL AND HISTORICAL DEVELOPMENT OF PHYSICAL MODELS AS A TOOL FOR PRESENTING THE PHYSICIST'S STRUGGLE TO UNDERSTAND NATURE TO STUDENTS IN LIBERAL ARTS PHYSICS COURSES. Randall Caton, Jane C. Webb and George R. Webb, Dept. of Physics and Computer Science, Christopher Newport College, Newport News, VA 23606. Helping students grasp the struggle that scientists undergo as they search for models to understand the universe is an important element in a course designed for liberal arts students who are not science majors. We complement the traditional problem-solving and conceptual models with a heavy emphasis on the actual development of the models themselves, talking about the work of individual scientists and of the political and social forces surrounding scientific efforts at model-making. Students are asked to write essays on homework and tests, essays that are more typical of English and history courses. For example, students answer questions such as this one. "Maxwell and Einstein are both associated with radical changes in the model of light. Describe first the model as Maxwell found it, what he concluded, and what Einstein did to the model he inherited from Maxwell. Second, discuss the philosophical positions of Maxwell and Einstein concerning man's position in the universe. Speculate on whether these positions influenced or were influenced by the physicists' models."

ASE OUTPUT FOR SOLAR-PUMPED IODINE LASER.¹ Yong S. Cho* and In H. Hwang*, Dept. of Physics, Hampton Univ., Hampton, Va. 23668. Amplified spontaneous emission (ASE) pulse is obtained from an iodine photodissociation laser amplifier which uses $n\text{-C}_3\text{F}_7\text{I}$ as an active medium and is pumped with a long-pulse solar simulator (full width at half maximum = 1ms). By measuring the population inversion density in the active medium of the amplifier, we have obtained the threshold condition for the ASE. Threshold condition and ASE energy are measured as a function of the flashlamp input energy and of the amplifier length.

1. Work is supported by NASA grant # NAG 1-1091.

A SCHRODINGER SPREADSHEET. Don Chodrow, Dept. of Physics, James Madison Univ., Harrisonburg, Va. 22807. A spreadsheet is used to find the energy eigenvalues and eigenfunctions for the one-dimensional time-independent Schrodinger equation for several potentials of even parity. The spreadsheet's graphing ability is used to help find the eigenvalues and to display the eigenfunctions.

HARD-CORE FLASHLAMP PUMPED UV DYE LASER.¹ Jaeho Choi*, Kwang S. Han*, Dept. of Physics, Hampton Univ., Hampton, Va 23668. A near UV dye laser output was obtained by improving the hard-core flashlamp² (HCF) device which has been developed for dye lasers. The electrical discharge in the HCF is initiated by the surface discharge on an alumina insulator. The risetime of the HCF pumping light was $\approx 1.2 \mu\text{sec}$ which was fast enough to excite a near UV dye laser. The maximum output energy of the HCF pumped LD 390 dye laser was 67 mJ with argon as a working gas. When xenon gas was used as a working gas, the efficiency of the laser output was 0.1% which was comparable to that of the conventional linear Xe flashlamp. The optimum conditions of the near UV dye laser will be discussed.

1. Work is supported in part by ONR grant # N00014-89-J-1653 and in part by NASA grant # NAG 1-1091.
2. K.S. Han *et. al.*, ILS-V Conf. Bull. APS. 34, 1657 (1989).

A STUDY OF ENERGY TRANSFER(KERMA) OF NEUTRON FOR TISSUE-RESIDENT ELEMENTS. Sang Y. Chun, Dept. of Physics, Old Dominion Univ., Norfolk, VA 23529, John W. Wilson*, and Larry W. Townsend*, NASA Langley Research Center, Hampton, VA 23665. KERMA(Kinetic Energy Released in Matter) values for H, C, N, and O for neutrons of energies from 1 to 100 MeV are studied. There exist two sets of KERMA calculation for light nuclei($A < 20$) in which the nuclear statistical behavior is inadequate to adopt. One includes neutron energies from 20 to 80 MeV using Intranuclear Cascade Evaporation Code. The other set considered KERMA for thermal neutron using ENDF/B nuclear cross section data. As one of the ongoing data parameterization of nuclear data set for transport code we studied KERMA for tissue-resident elements. To give consistent connection between these two existing data sets, we recalculate KERMA using simple binary collision algorithm. Nonelastic cross sections are adopted from the BRYNTRN(Baryon Transport) computer code and ENDF/B-V nuclear data is used for total cross section of thermal neutron. The results are compared with two existing data sets of KERMA. (This work is supported by NASA grant.)

GAIN STABILIZATION AND MONITORING USING PULSED ULTRAVIOLET LASERS. P. Denholm, K. Giovanetti, C. Hogue and K. Healey. Dept. of Physics, James Madison University. Nitrogen gas discharge lasers emit very short duration bursts of intense ultraviolet radiation. A standard commercially available nitrogen laser can emit 100 μJ of energy in a pulse that has a duration from a few nsec to a few hundred picosec. The wavelength of this radiation, 337 nm, can be used directly to excite optical transitions in plastic scintillator. The ultraviolet radiation therefore produces a similar spectrum to that produced by a charged particle traversing the scintillator. The large amount of available energy, short pulse duration, and the similarity of response of the scintillator to uv light and to charged particles make nitrogen lasers ideal for calibrating and monitoring the time and energy response of detectors that use plastic scintillator. Our experience with gas discharge lasers and their use in calibrating scintillator will be discussed.

PARAMETERIZATION OF OFF-SHELL α - α TRANSITION AMPLITUDE.

Rajendra R. Dubey and Govind S. Khandelwal, Dept. of Physics, Old Dominion Univ., Norfolk, VA 23529. Francis A. Cucinotta, NASA Langley Res. Center, Hampton, VA 23665-5225. Using the separable potential model, we consider T-matrix for α - α scattering. The parameters of our model are constrained to phase shift data for the $L = 0, 2$ and 4 partial wave for the energy range of 0 - 100 MeV in the lab system. We will use this model to calculate the off-shell amplitude for α - α scattering which is input for a Faddeev model of the ^{12}C ground state. (Supported by the NASA Grant #NCCI-42).

METHODS OF HEAVY ION TRANSPORT STUDIES. Hamidullah Farhat, Dept. of Phys., Old Dominion Univ., Norfolk, Va. 23589, & J. W. Wilson and L. W. Townsend, NASA Langley Research Center, Hampton, Va. 23665-5225. The transport of high energy heavy (HZE) ions through bulk materials is studied with energy dependence of the nuclear cross sections being neglected. The approaches to the problem are both energy dependent and energy independent, where the lower order approximation will be totally energy independent. The first and essential assumption to the energy independent case is the high energy characterization of incident beam. A three term expansion appears to be adequate for most practical applications for which penetration depths are less than 30 g/cm^2 of material. The differential energy flux is found for monoenergetic beams and realistic ion beam spectral distributions. The energy independent case has been solved to get the total flux and the fluxes of any individual collision terms up to the fourth collision term. An approximate formalism is given to estimate higher order terms.

SERIAL CORRELATION INFORMATION IN RESOURCE OPTIMIZATION MODELS. Lawrence E. Flynn, Dept. of Math., Hampton Univ., Hampton, VA 23668. The explosion of available computational power to apply to hydrological modelling has significantly increased the use of simulation methods (ARIMA, etc.). The basic problems of selecting the physically and economically important characteristics of the historic data to include in such simulation methods remain. The ability to produce and use millions of synthetic flow values in an economic model is spurious unless the proper (relevant) factors are included in the generation of the time series. This talk presents a discussion of a variety of simulation methods based on their relationships with historical data and their compatibility with design and operation optimization models for reservoirs. While the discussion is often based on mathematical analysis, the bottom line should be the ability of a method to work (give good results). Mathematical complexity is not a goal of water resource management.

PHOTODIODES AND THEIR USE AS ULTRAVIOLET RADIATION DETECTORS.

C. Hogue, P. Denholm, K. Giovanetti, and K. Healey. Dept. of Physics, James Madison University. Photodiodes have been used to measure both the starting time and the intensity of a pulse of ultraviolet radiation from a gas discharge nitrogen laser. These photodiodes will be incorporated into a laser calibration system that will measure the response of one of the large particle detectors under development for CEBAF, the Continuous Electron Beam Accelerator Facility. The calibration system will consist of a network of optical fibers that distributes pulses of ultraviolet light to various components of the detector. The response of the detector components to a known amount of uv light can be used to calibrate and monitor detector performance. An overview of photodiodes and a description of their use in a detector calibration system will be given.

The Effect of the Buffer Gas Helium on the Vibrational Relaxation of Diatomic Bismuth.¹ Seog S. Jang* and Nelson W. Jalufka*, Dept. of Physics, Hampton Univ., Hampton, Va. 23668. The absorption cross section of the $A \leftarrow X$ system of Bi_2 , which has a maximum of about $4 \times 10^{-17} \text{ cm}^2$, was estimated by measuring the absorption spectrum in the wavelength region 450-650 nm. The fluorescence of Bi_2 , excited by a CW Ar^+ laser (514.5 nm) which excites mainly the $v''=4 - v'=19$ transition of $A \leftarrow X$ system of Bi_2 , was measured in the region 480-580 nm at 850°C. The fluorescence of Bi_2 with 3 Torr helium (about $2 \times 10^9 \text{ sec}^{-1}$ collision frequency at 850 °C) was recorded. There was no evidence of vibrational energy transfer to adjacent level at a collision frequency of $2 \times 10^9 \text{ sec}^{-1}$. With 15 Torr helium (about 10^{10} sec^{-1} collision frequency at 850°C), the fluorescence disappeared.

1. Work is supported by NASA grants No. NCC 1-137 and NAG 1-1091

ELECTRON TRANSPORT IN THE STOCHASTIC FIELDS OF RFP ZT-40. Myung-Hee Kim* & Alkesh Punjabi, Dept. of Mathematics, Hampton Univ., Hampton, Va 23668. The three basic mechanisms that produce either classical or anomalous transport are: spatial variation of magnetic field strength, spatial variation of electrostatic potential in magnetic surfaces, and the loss of magnetic surfaces. A Monte Carlo code has been written to study transport due to these three mechanisms interacting with collisional effects. The equations of motion are obtained from the canonical drift Hamiltonian, but non-canonical, rectangular coordinates are used to simulate the particles which pass through or are in very close proximity of the magnetic axis. The code has been applied to the reversed field pinch ZT40. For ZT40 the Bessel function model has been used to represent the magnetic field geometry. The effects of pitch angle scattering, loop voltage, and the break-up of magnetic surfaces resulting from resistive MHD perturbations on the drift particle trajectories are illustrated. The particle diffusion coefficients are obtained for varying amplitudes of resistive MHD perturbations.

NEW VERSIONS OF THE HILLE-YOSIDA THEOREM. Ridgley Lange, Mathematics, Hampton University, Hampton, VA 23668. In some applications it may happen that the classical one-parameter semigroup theory on Banach space may be inadequate, because the condition of strong continuity of the semigroup may be too stringent for many situations in which we may still like analogs of the classical results. In this talk we present the construction of a new class of weakly continuous semigroups which are not strongly continuous and which depend on the weaker notion of the Pettis (rather than Bochner) integral in Banach spaces. As a result we call these semigroups "weakly Y-integrable" where Y forms a duality with the underlying Banach space and relative to which the weak integral is defined. We give some elementary properties of weakly Y-integrable semigroups; many of these have classical analogs but are now expressed in terms of the "Y-topology." Finally we state an analog of the classical Hille-Yosida theorem, i.e. a theorem giving sufficient (and necessary) conditions that a given operator A generate a weakly Y-integrable semigroup. Comments on the proof will also be given.

UNIVARIATE IMBEDDING OF MULTIVARIATE STATIONARY SEQUENCES. A. G. Miamer, Dept. of Mathematics, Hampton Univ., Hampton, VA 23668. It is shown that any multivariate stationary sequence can be imbedded in a naturally defined univariate stationary sequence.

NUCLEAR FRAGMENTATION STUDIES FOR CMOS SRAM APPLICATIONS. D.M. Ngo, J.W. Wilson, L.M. Townsend, F.A. Cucinotta, G.S. Khandelwal. Dept. of Physics, Old Dominion University, Norfolk, VA 23529. This report is a development of a simulation technique for modeling the energy deposition by energetic protons in modern integrated circuits. Such a technique allows prediction of the Single Event Upsets (SEU) in microelectronic memories which are exposed to the space radiation environment typical of satellite orbits. The mode examines the process of target nucleus fragmentation by energetic protons and their potential effects on microelectronic devices. The model calculations are compared with the pulse-height spectra experiments of the surface barrier detectors measured by McNulty, Farrel and Tucker for thin slabs of silicon exposed to proton beams at various energies.

The SEU experiments for a 16-K CMOS SRAM (16 kilobits complementary metal oxide semiconductor static random access memory) which are 1 μ m twin tube technology with different feedback resistor values were conducted at NASA-Van de Graff SEU Facility of Brookhaven National Laboratory.

LINEAR POWER SUPPLY DESIGN. Joseph W. Rudmin, Physics Dept., James Madison University, Harrisonburg, Va. Design of the most widely used of all electronic circuits for the last fifty years--the simple regulated linear power supply--is not correctly taught in any text, nor has it been correctly understood, even in the simplest approximations. Design in the usual sense of choosing devices with the correct relevant parameters in order to achieve a final circuit with predictable behavior, is not even possible, since the transformer manufacturers themselves do not specify and do not even usually KNOW the most important parameter--the resistance of the transformer windings. The design technique recommended by modern transformer manufacturers relies on empirical curves published in 1943, which cannot be validly applied. [1] The history and description of the problem, useful models for transformer behavior, and approaches to its solution, will be presented. [1] O. H. Schade, Proc. IRE 31, pp 341-61 (1943).

NEW TRENDS IN TEACHING INTRODUCTORY PHYSICS. Raymond A. Serway, Dept. of Physics, James Madison University, Harrisonburg, Va. 22807. The purpose of the Introductory University Physics Project (IUPP), which started in 1987, is to examine the calculus-based introductory physics course and to create new models that will be appropriate for classroom use. This presentation will review the guidelines of this program, and the issues addressed by the various working groups in IUPP. The approaches and contents of two model programs developed at Pomona College and the U.S. Air Force Academy will be reviewed. Finally, the author will suggest a Table of Contents for a textbook which could be used in such new approaches (a two-semester course) which emphasizes the "less may be more" theme.

PERFLUORO-T-BUTYL IODIDE AS AN EFFICIENT LASER MEDIUM FOR SOLAR PUMPING IN SPACE. Bagher M. Tabibi*, Abdulaziz M. Gambo, Demetrius D. Venable, Calvin W. Lowe*, Dept. of Physics, Hampton Univ., Hampton, Va 23668, and Ja H. Lee, NASA Langley Research Center, Hampton, Va 23665-5225. A comparative study of laser characteristics of t-C₄F₉I to that of the widely used n-C₃F₇I under closely-simulated-AMO-solar pumping is reported. The closely-simulated-AMO solar spectrum was obtained by using an acetone-water(1:200) filter around the laser tube. The laser output of t-C₄F₉I was measured to be 2.6 to 5 times that of n-C₃F₇I at fill pressures ranging from 60 torr to 5 torr. The higher laser efficiency of t-C₄F₉I resulted mainly from a better solar energy utilization and consequently, a larger photodissociation rate. The iodide t-C₄F₉I has also shown near complete chemical reversibility. (This work was supported by NASA LaRC Advanced Solar Energetics program under grant # NAG-1-1091.)

THE PHOTOELECTRIC EFFECT - AN OLD EXPERIMENT WITH NEW TECHNOLOGY. Matthew A. Willis and Gerald R. Taylor, Jr., Physics Department, James Madison University, Harrisonburg, VA 22807. A Leybold phototube and Keithley 485 picoammeter have been interfaced to a 386-PC computer to automate the photoelectric effect experiment. The phototube is driven directly by D/A (digital to analog) conversion from the computer. Picoampere photo-currents are measured by the Keithley 485 picoammeter and transferred to the computer through an IEEE-488 interface. The data acquisition and control software is written in GW BASIC. Various light sources, mercury, sodium and a HeNe laser, have been used. A description of the experiment, interfacing and data acquisition is presented.

Biology

DEFOLIATION AND PLANT COMPETITION EFFECTS ON CANADA THISTLE AS INFLUENCED BY PRECIPITATION AND FERTILIZERS. B. N. Ang and L. T. Kok. Dept. of Entomology, VPI & SU, Blacksburg, VA 24061. Field studies were conducted on the effects of level of artificial defoliation, frequency of the defoliation, and plant competition from Tall fescue and Crown vetch on Canada thistle. In a wet year (1989), plant competition had the greatest impact on 4 (dry weight of above, and below ground parts, length of roots \geq 3mm in diameter and number of plants produced per original plant) out of 7 parameters measured, while level of defoliation had the greatest impact on the remaining 3 parameters (% nonstructural carbohydrate content, total nonstructural carbohydrate produced and plant height). However, in a dry year (1990) plant competition had the greatest impact on only 2 (dry weight of above ground parts and length of roots \geq 3mm in diameter) out of the 7 parameters, with level of defoliation having the greatest impact on the remaining 5 parameters. Application of P and K fertilizers in a dry year had no apparent impact on all the parameters measured.

GUIDELINES FOR LABORATORY HANDLING AND MANIPULATION OF THE ZEBRA MUSSEL

Joseph R. Bidwell , J.L. Farris*, D.S. Cherry*, Dept. of Biology, Virginia Polytechnic Institute and State University, Blacksburg, Va. 24061, & H.E. Kitchel*, Virginia Department of Game and Inland Fisheries, Richmond, Va. 23230.

The zebra mussel, *Dreissena polymorpha*, is an introduced bivalve whose North American range is currently limited to the Great Lakes. Its potential to proliferate, in addition to documented incidents of impact on native fauna and biofouling of municipal and industrial water systems has generated serious concerns. From past experience in developing control methodologies for the Asiatic clam, *Corbicula fluminea*, researchers at Virginia Tech were asked to conduct laboratory research on the sensitivity of *Dreissena* to various biocides, and in 1990 were granted a state permit to obtain the organisms. Specific concern in holding the mussels included the accidental release of veliger larvae in wastewater or through spills, and the removal and release of adult mussels. In accordance with guidelines developed to address these problems, the mussels are kept in a secure, limited access holding facility, with water temperature kept below 12 °C to avoid reproductive activity. Holding water is also regularly checked for the presence of free swimming veligers, while all wastewater and equipment with which the mussels have had contact is both chlorine and heat treated. A continuing census of adult mussels is maintained to track their use and disposition. Early data suggest that control procedures used on *Corbicula* can be applied to the zebra mussel with similar success.

THE RELATION BETWEEN WETLANDS VEGETATION COMMUNITIES AND GROUND WATER INDUCED SALINITY GRADIENTS. John W. Blankenship, William G. Reay and Dr. George M. Simmons, Jr., Dept. of Biology, Va. Polytechnic Inst., Blacksburg, Va. 24061. Wetlands serve a wide variety of ecological functions, and may be characterized by diverse vegetation communities. It has been shown that plant species distribution and complexity, increase with decreasing salinity concentrations. The objective of this study was to investigate plant species distribution and diversity in relation to interstitial salinity concentrations. Research was conducted along a 360 meter transect incorporating oligohaline to euhaline conditions. Plant species number and percent cover were determined by meter squared quadrat. Interstitial pore water was analyzed for salinity with an inductive salinometer. Results indicate a relation between ground water induced salinity gradients and plant species distribution and diversity. (Partially supported by the Va. Div. of Soil and Water Conservation.)

VARIATION IN MICROTINE BIOENERGETIC STRATEGIES AND THE ADAPTIVE CAPACITY OF THE GUT. Becke A. Bogue & T. L. Derting, Dept. of Biol., Hollins Col., Roanoke, Va. 24020. This study investigated gut morphology and its relationship to energy use in Microtus pennsylvanicus and M. pinetorum. Maximum energy utilization rates of M. pennsylvanicus are twice that reported for M. pinetorum. This may be related to species differences in the adaptive capacity of the gut. Adult females of each species were implanted with thyroxine pellets to increase energy demand and compensatory changes in the gut were determined. In both species body mass and dry matter digestibility did not change significantly with increased energy demand. However, digestion rate increased significantly while the turnover time of digesta and the mass of gut contents decreased. In the gut, caecum length and the mass of absorptive tissue increased. The jejunum mucosa dry mass, ileum dry mass, and mucosa:serosa ratio in the jejunum and ileum each increased significantly. In all cases, the gut changes that occurred were greater in M. pennsylvanicus than in M. pinetorum. The greater ability to M. pennsylvanicus to utilize energy resources may, therefore, be partially due to the greater adaptive capacity of their gut.

THE EFFECT OF REMOVAL OR IMPAIRMENT OF THE VOMERONASAL ORGAN ON RECOVERY FROM REPRODUCTIVE INHIBITION OF PRAIRIE DEERMICE FROM LABORATORY POPULATIONS.

Tama C. Cathers, E. L. Bradley, Biology Department, Col. of William and Mary; C. J. Wysoki, Monell Chemical Senses Center, Philadelphia, PA; C. R. Terman, Biology Department, Col. of William and Mary, Williamsburg, VA 23185. The vomeronasal organ (VNO) has been implicated in recovery from reproductive inhibition of mice (*Peromyscus maniculatus bairdii*) from laboratory populations. We investigated the effects of removal of the VNO (VNX) on recovery from reproductive inhibition. In males, VNX significantly ($P < 0.05$) decreased recovery, based on testes and seminal vesicle weights, seminiferous tubule cross-sectional areas, and numbers of elongated spermatids per seminiferous tubule. Partial removal of the VNO, termed VNO-impairment, led to recovery intermediate to that of fully VNX and Sham-surgery animals. In females, no significant differences ($P < 0.05$) in recovery were found.

(Supported by a William and Mary Minor Grant)

EFFECTS OF AFLATOXIN B₁ IN SEVERAL STRAINS OF *DROSOPHILA MELANOGASTER* AND POSSIBLE CORRELATIONS WITH MITOCHONDRIAL-DNA. Joseph P. Chinnici, and Christopher R. Warren, Dept. of Biol., Box 2012, Va. Commonwealth Univ., Richmond, Va. 23284. Ten natural populations of *Drosophila melanogaster* were sampled from different localities in Virginia, and a collection (Hale and Singh, 1987) of five different worldwide populations of *D. melanogaster* were tested for levels of response to Aflatoxin B₁ (AFB₁) toxicity. Twenty-five eggs from each sample were fed medium containing various concentrations of AFB₁ (0.00, 0.75, 1.50 ppm). The Virginia and worldwide strains demonstrated a variety of responses including a significant decrease in numbers of pupal cases, adults, female and male body length, and increased egg-to-pupal, and egg-to-adult development times with increasing AFB₁ concentrations. Variation in the mitochondrial - DNA (mt-DNA) haplotypes in the worldwide strain populations appears to be a cytoplasmic contributing factor for the differences seen between strains relatively resistant or sensitive to AFB₁. (Supported by grants from the Undergraduate Research Committee of Va. Commonwealth Univ. and the Virginia Academy of Sciences.)

QUANTITATIVE COMPARISON OF IMMUNE SYSTEM COMPONENTS AROUND NORMAL AND RESORBING MOUSE EMBRYOS. G. A. Clarke and A. F. Conway, Dept. of Biol., Randolph-Macon Col., Ashland, Va. 23005 and C. M. Conway, Dept. of Biol., Va. Commonwealth U., Richmond, Va. 23284. CBA/J female mice mated with DBA/2J males were injected i. p. with 0.2 ml of 250 ug/ml poly I:C in PBS or with PBS on day 6 of gestation and sacrificed on day 7, 8, 9, or 10 of gestation. Implantation sites were removed, separated, frozen in hexane chilled with liquid nitrogen, and sectioned at 20 um on a cryostat. Structures stained by immunoperoxidase procedures against macrophages, asialo GM1 (natural killer cell marker), immunoglobulin A (IgA), and immunoglobulin M (IgM) were counted and evaluated by linear regression analysis. Poly I:C injection did not increase the incidence of resorptions detectable by day 10. Phagocytic vacuoles in trophoblastic giant cells (TGCs) stained strongly for IgA, IgG, and IgM and weakly for macrophage markers and asialo GM1. Cells which stained for macrophage markers were observed in TGC vacuoles, indicating phagocytosis of macrophages. Counts of macrophages and natural killer cells were negatively correlated, suggesting an antagonistic relationship. Counts of natural killer cells were also positively correlated with IgA in TGC vacuoles and counts of macrophages were also positively correlated with IgM in TGC vacuoles.

EASTERN CHIPMUNK (Tamias striatus) NESTS, ACTIVITY, AND FOOD HOARDING. Jack A. Cranford, Dept. of Biology, Section of Ecology and Environmental Biology and Museum of Natural History, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. Adult chipmunks exhibit seasonal patterns of body mass changes which can be identified in a well known field population. In order to characterize these mass changes, individual age cohorts must be well known which requires trapping every 14-21 days for 5 or six days. Using body size, mass and the presence of a well developed temporal ridge juveniles and most subadults can be properly assigned to a cohort. Plots of field mass data show that growth rates of fall and spring born animals differ. Burrow systems are extensive often exceeding 900 cm in length and having from 3- 5 chambers for nesting and/or cache storage. Scatter hoards vary by season and by the association distance between burrows. Field hoarding experiments show that hoarding behavior varies with distance to the source, food amount and type, and the presence of conspecifics.

THE EFFECT OF SOCIAL POSITION ON SERUM CORTICOSTERONE IN PRAIRIE DEERMICE (PEROMYSCUS MANICULATUS BAIRDII). Steven H. Crossman, E. L. Bradley, and C. R. Terman, Biology Department, Col. of William and Mary, Williamsburg, VA 23185. Serum corticosterone levels and adrenal and reproductive organ weights were studied in dominant, subordinate, and control mice (Peromyscus maniculatus bairdii). There were no significant differences discovered between dominant and subordinates or among dominants, subordinates, and controls in any of the measured variables: body weight at death, absolute and relative paired seminal vesicle weights, absolute and relative paired testes weight, and serum corticosterone levels. These data suggest differences between Peromyscus and Mus.

(Supported by a William and Mary Minor Grant)

ANALYSIS OF METABOLIC REQUIREMENTS FOR PERITHECIAL DEVELOPMENT IN PODOSPORA ANSERINA NIESSL. Melissa Daly and James E. Perham, Dept. of Biology, Randolph-Macon Woman's Col., Lynchburg, Va. 24503. Induction of sexuality in Podospora anserina requires low concentrations of nitrogen compounds and carbohydrates. Follow-up research in this laboratory shows the importance of zinc in the development of the perithecium. Examination of zinc's role in this formation has led to studies of the participation of the divalent anion as an inorganic cofactor in proteolytic reactions. It has been established in the literature that zinc plays an important role in both aminopeptidase and carboxypeptidase activities. The objective of this paper is to evaluate the requirement for zinc and aminopeptidase activity in perithecial development. To meet this objective, hydrolysis of eighteen beta-naphthylamide amino acid substrates was observed to determine the need of zinc as a cofactor. Of the eighteen hydrolytic reactions, only those involving tyrosine beta-naphthylamide and phenylalanine beta-naphthylamide require zinc.

THE EFFECTS OF PREGNANCY ON THERMOREGULATORY BEHAVIOR OF THE VIVIPAROUS LIZARD CHALCIDES OCELLATUS. Elizabeth F. Daut, Dept. of Biol., VPI&SU., Blacksburg, Va. 24061. Selected body temperatures of the scincid lizard Chalcides ocellatus were measured on a thermal gradient during five (two week) observation periods between April and September. Body temperatures of females and males did not differ in April and September. However, body temperatures of females were greater than males by as much as 1°C in June and July when females were pregnant or shortly post-partum. Maintaining high estimated body temperatures while pregnant may enhance the survival of developing embryos. Individuals also exhibited consistent temperature preferences across the entire study period, that is, individuals with relatively high body temperatures in April exhibited relatively high body temperatures in all other periods (Friedman two-way ANOVA by ranks, $P < 0.05$).

LEPTINIDAE (COLEOPTERA) IN VIRGINIA. Ralph P. Eckerlin and Harry F. Painter, Natural Sciences Division, Northern Virginia Cmnty. Col., Annandale, VA 22003. The genus Leptinus includes three Nearctic species; Leptinus americanus, L. occidentamericanus, and L. orientamericanus. The latter species is the only one known to be present east of the Mississippi River. Virginia was heretofore represented by only three records; 34 specimens from "mole fur", Culpeper County; 2 "on mole", Montgomery County; and 2 on Scalopus aquaticus, without other data. New state records from Fairfax, Highland and Tazewell Counties, and a new host record from Condylura cristata are presented. With the addition of Condylura, all 5 mole genera present in North America are known to host Leptinus. In our study, 3 of 44 Blarina brevicauda, 1 of 2 Condylura cristata and 1 of 8 Scalopus aquaticus harbored leptonids. The beetles are blind, dorso-ventrally flattened and covered with caudally directed stout hair or setae. Species are differentiated by genitalic characteristics. Morphological and behavioral characteristics suggest a long association with insectivores as ectoparasites or phoronts.

EFFECTS OF CHANGING LAND USE PATTERNS ON BOBWHITE QUAIL HABITAT IN VIRGINIA. Michael L. Fies, Dept. of Game & Inland Fish., Charlottesville, Va. 22901, Irvin L. Keynon, Jr.*, Dept. of Game & Inland Fish., Ashland, Va. 23005, Jack V. Gwynn*, Dept. of Game & Inland Fish., Charlottesville, Va. 22901. Bobwhite quail (Colinus virginianus) populations have been steadily declining in Virginia for at least 50 years. Loss of farmland habitats and changing farm practices are believed to be the primary factors responsible for this decline. The total number and acreage of farms in Virginia has declined substantially since 1920. Many abandoned fields have reverted to forest that is no longer suitable for quail. A rapidly expanding human population now occupies many areas of former quail habitat. The production of diverse mixtures of cereal grains has been replaced by monocultures of soybeans and improved grassland. Cattle production has increased, while the total acreage of pasture land has declined. The intensity of land use on farms has increased dramatically. Changing farm practices such as the removal of fencerows, fall plowing, double cropping, and the increased use of agricultural chemicals have also been detrimental to quail. The fragmentation of remaining habitats has increased the vulnerability of quail to predation and hunter harvest. Quail populations are expected to continue declining if current patterns of land use persist.

THE MESOZOIC VERTEBRATES OF VIRGINIA. Nicholas C. Fraser, Virginia Museum of Natural History, Martinsville, VA 24112. To assess man's impact on modern biota requires an awareness of past extinction events. Mass extinctions have long been recognized in the fossil record. The end Permian extinction was by far the greatest of these and the terminal Cretaceous event is well known for the demise of the dinosaurs. However the exact nature, timing and causes of such events are still disputed. Large scale global extinctions are known to have occurred at the end of the Triassic period. Research on Late Triassic sediments in Virginia is beginning to shed considerable light on global events at this time.

MORTALITY FACTORS AFFECTING COTESIA GLOMERATA (HYMENOPTERA:BRACONIDAE), A GREGARIOUS PARASITE OF THE IMPORTED CABBAGEWORM. David N. Gaines and L. T. Kok, Dept. of Entomology, Va. Polytechnic Inst. and State Univ., Blacksburg, Va 24061. Cotesia glomerata oviposits multiple eggs into early instar imported cabbageworm larvae, Pieris rapae (Lepidoptera:Pieridae). The resulting parasite larvae consume their host from within, killing it before exiting to spin cocoons in a mass. C. glomerata cocoon masses were collected weekly in 1989 & 90 from field plots of broccoli and cabbage in order to determine the extent of hyperparasitism. The cocoons were held in containers in the laboratory and all exiting parasites and hyperparasites were counted. Several species of hyperparasites emerged, and dead cocoons were dissected to determine the cause of mortality. Total mortality averaged 44.7% in 1989 and 47.7% in 1990. Hyperparasitism accounted for 10.2 and 39.8% for 1989 and 1990, respectively. A large part of mortality could not be attributed to any single factor, but dissections of dead cocoons revealed failed hyperparasitism to be a factor in only 2.3% of total cocoons. Increased incidence of dead cocoons correlates with rainfall, indicating rainfall as a mortality factor. Superparasitism may also be a factor because higher numbers of dead cocoons were seen in large cocoon masses.

LIFE HISTORY CHARACTERISTICS OF BOYERIA VINOSA (ODONATA:AESHNIDAE) IN A SOUTHWESTERN VIRGINIA MOUNTAIN STREAM. G. H. Galbreath and A. C. Hendricks, Dept. of Biol., VPI&SU, Blacksburg, Va. 24061. Boyeria vinosa were univoltine at the study site on Chestnut Creek Virginia. Development was rapid during the early instars (Jul-Aug) while most weight gain occurred during the final instars (Sep-May). Gut content analysis was used to determine prey preference by comparing the prey consumed with available prey present in the environment over a three year period (1988-90). Prey was selected in roughly the same proportions as they occurred in the environment with Trichoptera, Diptera, and Ephemeroptera larvae comprising the majority of the diet. Ephemeroptera were preferentially selected when abundant. Although Oligochaete abundance was high, B. vinosa did not utilize this prey item. Our data indicate prey activity, microhabitat selection, and seasonal abundance are all important in determining prey preference of B. vinosa.

LAND-USE CHANGES IN SOUTHERN VIRGINIA PIEDMONT, 1917 TO PRESENT. Stanley R. Gemborys & Anne C. Lund, Dept. of Biology, Hampden-Sydney College, Hampden-Sydney, VA 23943. A knowledge of the magnitude of changes in land-use is essential in order to properly evaluate the current composition of our ecosystems and to understand the patterns of development they will follow in the future. We are all familiar with the classical old field-pine-hardwood successional scheme observed in the southern Virginia Piedmont but many of us have limited quantitative knowledge of the area occupied by each of these vegetation types and the dynamic changes they have taken over time. This study deals with the changes in land-use and physiognomy that have taken place near Hampden-Sydney College and in the Appomattox Court House National Historical Park. The land located where Hampden-Sydney College now stands and the surrounding area has been subject to environmental manipulations since at least before 1776, the founding date of the College. The Appomattox Court House area has been inhabited since the late 1700's. Since then, the human population of these areas has changed dramatically. Land uses have also changed significantly. Information developed in this study is based on photo interpretation and measurements of aerial photographs supplied by the Soil Conservation Service of the United States Department of Agriculture. These photos were flown in 1937, 1949, 1972, and 1980 (Hampden-Sydney) and 1937, 1949, 1970, and 1984 (Appomattox). Based on the 1937 photographs and a knowledge of successional patterns, we were able to confidently predict the composition of stands in existence in 1917. Forested land increased from about 40 percent coverage in 1937 to over 90 percent in the mid-1980's, with a corresponding decrease in open land.

TERRESTRIAL MAMMALS OF VIRGINIA: TRENDS IN DISTRIBUTION AND DIVERSITY. Charles O. Handley, Jr. Smithsonian Institution, Washington, DC 20560. The present mammal fauna of Virginia formed during the post-Pleistocene warming trend. Indians had little impact on the fauna, but European introduction of firearms led to terminal exploitation of bison and elk and to deliberate extirpation of large predators. Logging, clearing for agriculture, and urbanization had a negative impact on some forest species and brought gains for some open country species. The present era of conservation attempts to maintain diversity and to stabilize the fauna through protection, restoration, and management. Predictable future threats to mammals are from pressure of an expanding human population, global warming, and severe environmental perturbations such as acid rain and infestations of gypsy moths. Future challenges include maintaining large roadless and relatively trailless wild areas connected by forest corridors, establishing more and larger refuges to protect non-threatened as well as relict flora and fauna, acquiring fundamental knowledge of natural history of all species as a primary management tool, maintaining diversity and ecological equilibrium, and creating an informed and environmentally responsible citizenry through education and public relations.

SUCCESION AND HUMAN IMPACT EFFECTS ON HABITAT INFLUENCE ABUNDANCE AND SPECIES COMPOSITION--CASE HISTORIES WITH TIGER BEETLES. C. Barry Knisley, Dept. of Biol., Randolph-Macon Col., Ashland, VA. 23005 and James M. Hill, MD National Capital Park, 8000 Meadowbrook Rd, Chevy Chase, MD 20815. Tiger beetles occur in open habitats with bare soil and sunlight. Most species are highly habitat specific. Some Virginia species have probably been extirpated because of habitat disturbance or loss. Other species suffer local extirpation as habitats change through natural processes. Cicindela dorsalis media is abundant in sandy beach habitats of most of Virginia barrier islands, but on Assateague Island is limited to a few portions where ORV and pedestrian foot traffic are low. C. dorsalis dorsalis is common in many Chesapeake Bay beaches in Virginia but has been extirpated from most of the northeast where human impacts have been more severe. Cicindela abdominalis has apparently disappeared from the Zuni pine barrens because of increased density of vegetation caused by fire suppression. The natural succession at a borrow pit in Hanover Co. from an unvegetated open, wet flat to a dense pine woodland over a 10-year period resulted in the disappearance of Cicindela repanda, a riparian species, and changing abundance of C. sexguttata, a woodland edge species, and C. tranquebarica.

POPULATION DYNAMICS OF HOUSE MICE AND MEADOW VOLES ON A DREDGE DISPOSAL SITE. Georgia E. Kratimenos* and Robert K. Rose, Dept. of Biol., Old Dominion Univ., Norfolk, Va. 23529. A tag-and-release study was conducted for one year on Craney Island, a dredge disposal site in Portsmouth, Virginia. Craney Island provides good habitat for a feral population of *Mus musculus* because it is a highly disturbed area. A grid (.7 ha) was established with Fitch-live traps placed at trap stations at 10-m intervals. Animals were tagged with numbered metal ear tags. Seven species of small mammals were captured of which 65% were *Mus musculus* and 28% were *Microtus pennsylvanicus*. On average house mice were captured only twice, while meadow voles were captured three times. No significant differences from a 1:1 ratio were found for house mice; meadow voles had a significant difference ($p=.05$) in the sexes from a 1:1 ratio in two months of the study and in the total number of captured and tagged individuals. There were more males than females in all cases. Greatest densities for house mice occurred in November 1989, peaking at 104 individuals/ha; meadow voles peaked at 41 individuals/ha in the early fall 1990. Meadow voles were found to breed late into the winter months and then early in the spring, where house mice did not breed during the winter and began breeding later in the spring than the meadow voles.

HUMAN IMPACTS ON BARRIER ISLAND PIPING PLOVERS. John P. Loegering and James D. Fraser. Dept. of Fisheries and Wildlife, Va. Polytechnic Inst. and State Univ., Blacksburg, Va 24061-0321.

The Piping Plover (*Charadrius melodus*) is a small sand-colored shorebird. It has been listed as threatened throughout most of its range, including the Atlantic coast population, since 1986. Predation and human impacts appear to be affecting population levels. Commercial and residential development cause habitat loss. Breeding habitat may also be altered by projects to protect such development such as dune building, dune stabilization, and beach revegetation. Heavy beach use by recreationists can lower reproductive success by disturbing plovers or excluding them from prime foraging areas. Off-Road-Vehicle traffic causes direct mortality on chicks and eggs, and also disturbs adult and young plovers. Breakwater and jetty constructions that prevent natural overwashing reduce the maintenance and creation of nesting habitat. Future development and recreational activities will need to be managed to minimize conflicts with this sensitive species.

EFFECTS OF ADOLESCENT PHENOBARBITAL TREATMENT ON THE MICROANATOMY OF THE CEREBELLAR CORTEX OF MICE. E. A. Martin, P. L. Dementi and A. F. Conway, Dept. of Biol., Randolph-Macon Col., Ashland, Va. 23005. Fifteen one month old female CD-1 mice received 0.165 mg/L phenobarbital in their drinking water for two months while 15 controls received plain water. The cerebellum was fixed by perfusion and embedded in glycol methacrylate. Sagittal sections taken from 1 mm to the right of the mid-sagittal plane were stained with Azure A and Eosin B. Cell counts from the granular, Purkinje, and molecular layers at the deep, middle, and outer areas were sampled on Folium IV (ventral surface), Folium V (dorsal surface), and Folium IX (dorsal surface). No pattern of damage was common to all areas sampled, but significant differences (t-test) in Golgi neuron, granule cell, Purkinje neuron, stellate neuron, oligodendroglial, and microglial populations occurred in specific areas, most often in the outer region of the folia. These results suggest a site-specific rather than a cell-specific pattern of histological damage caused by adolescent administration of phenobarbital.

BENZODIAZEPINES, MAO INHIBITORS AND TRICYCLICS: Determining positive chemotaxis and increased IL-1 β production by P338D₁ cells. Rebecca S. McHugh* and Rosemary Barra, Dept. of Biological Sciences, Mary Washington College, Fredericksburg, VA 22401. The chemotactic effects of four psychopharmaceutical agents on macrophage-monocyte cultures (P388D₁ cell line) were measured by three different assays, Transwell chambers, Blindwell chambers and Agar diffusion tubes. All three indicated a stimulatory effect from the drugs compared to the control.

Both the blindwell and the transwell chambers showed similar results, with Valium having the more potent effect and the greatest effect at 10⁻⁸ percent concentration. Tofranil, Zantac and Librium all indicated increased chemotactic effects, Librium having the least stimulation and Tofranil and Zantac having greater effects at higher concentrations.

In the agar diffusion tubes the exact concentrations of the drugs could not be determined in each section, however, this technique does demonstrate significant cellular migration. All the drugs tested had increased migratory effects compared to the control. Although chemotaxis was an apparent property of these drugs, increased secretion of IL-1 β by the cells was not detected.

WHITE-TAILED DEER AS KEYSTONE SPECIES WITHIN FOREST HABITATS OF VIRGINIA. William J. McShea and John Rappole, National Zoological Park, Conservation and Research Center, Front Royal, VA. 22630. Two potential pathways by which deer may influence the abundance and distribution of other vertebrate species are, first, directly by competing for limited resources; and second, indirectly by altering habitat features. If deer have a significant impact on forest habitats, evidence for direct competition may be consumption of mast by deer, and evidence for habitat alteration may be reduced densities of understory vegetation. Both mast crops and understory vegetation are limiting factors within forest habitats, as preliminary data indicate small mammal densities in the spring are limited by the size of the mast crop the previous autumn and the composition of the understory bird community is correlated with the density of understory vegetation. The select exclosure of deer from 4 of 8 study areas within the Shenandoah National Park and the Conservation and Research Center will allow deer impacts along both these pathways to be assessed.

LENGTH AND BREADTH OF EGGS OF GLOBODERA TABACUM VIRGINIAE AND G. T. SOLANACEARUM. L. I. Miller*, Dept. of Plant Path., Phys. and Weed Sci., VPI & SU, Blacksburg, VA 24061. Comparisons were made of the length (L) and breadth (B) of unsegmented eggs (EUS) and eggs with second-stage juveniles (EJ2) from cysts of type locality isolates of Globodera tabacum virginiae (N1) and G. t. solanacearum (N2) cultured on Solanum carolinense (P1) and 'VA 312' tobacco (P2). P1 and P2 were efficient hosts for N1 and N2. Mean dimensions in μ m of 125 specimens were as follows — L EUS: N1P1 963.7, N2P1 921.9, N1P2 939.0, N2P2 923.4; L EJ2: N1P1 981.9, N2P1 932.6, N1P2 958.6, N2P2 943.5; B EUS: N1P1 412.4, N2P1 425.1, N1P2 417.2, N2P2 430.3; B EJ2: N1P1 414.9, N2P1 428.4, N1P2 413.2, N2P2 434.9. Comparisons between the subspecies on P1 and P2 were significantly different ($P=0.05$) for the B EUS, B EJ2, L EUS and L EJ2 dimensions, except that dimensions for L EJ2 of N1 and N2 on P2 were not significantly different. Dimensions of L EUS and L EJ2 for N2 on P1 and P2 were not significantly different but dimensions were significantly greater ($P=0.05$) for N1 on P1 of L EUS and L EJ2 than on P2. Dimensions of B EUS and B EJ2 for N1 on P1 and P2 and of B EUS for N2 on P1 and P2 were not significantly different. Dimensions for B EJ2 were greater ($P=0.05$) for N2 on P2 than on P1.

MORPHOLOGICAL COMPARISONS OF THE CYST PERINEAL REGION AND GRANEK'S RATIOS OF GLOBODERA TABACUM VIRGINIAE AND G. T. SOLANACEARUM. L. I. Miller*, Dept. of Plant Path., Phys. and Weed Sci., VPI & SU, Blacksburg, VA 24061. Comparisons were made of the perineal region from cysts of type locality isolates of Globodera tabacum virginiae (N1) and G. t. solanacearum (N2) cultured on Solanum carolinense (P1) and 'VA 312' tobacco (P2). Mean dimensions in μm or ratio values of 125 specimens were as follows-- width of vulval fenestra (W) : N1P1 18.2, N2P1 21.0, N1P2 16.4, N2P2 20.3; fenestral length (L): N1P1 19.7, N2P1 23.7, N1P2 19.1, N2P2 24.9; diameter of fenestra ($W+L/2=D$): N1P1 18.7, N2P1 22.6, N1P2 17.8, N2P2 22.6; anus to fenestra (B): N1P1 52.1, N2P1 47.9, N1P2 48.3, N2P2 51.1; Graneck's ratio (B/D): N1P1 2.8, N2P1 2.2, N1P2 2.8, N2P2 2.3. Comparisons between the subspecies on P1 or P2 were significantly different ($P=0.01$) for the W, L, and D dimensions and B/D ratios but not for the B dimensions. Dimensions of W for N1 and N2 were greater on P1 than on P2 ($P=0.05$). The L dimensions for N1 were not significantly different on P1 or P2 but dimensions for N2 on P2 were greater than on P1 ($P=0.01$). The B/D ratios within nematode subspecies on P1 and P2 were not significantly different.

FREE-RANGING DOMESTIC CAT PREDATION ON NATIVE VERTEBRATES IN RURAL AND URBAN VIRGINIA. Joseph C. Mitchell, Dept. of Biology, University of Richmond, Richmond, VA 23173, & Ruth A. Beck, Dept. of Biology, College of William and Mary, Williamsburg, VA 23185. Imported into the United States in the early 1800s to control rodents in eastern cities, domestic cats (Felis catus) have become major predators of native vertebrates. We studied the diversity and seasonality of cat predation on native Virginia vertebrates in a rural environment July 1989 - November 1990 and in an urban environment January - November 1990. A total of 30 species (8 of birds, 2 amphibians, 10 reptiles, 10 mammals) were captured by a single rural cat. One was a mammal of special concern (star-nosed mole). Four urban cats captured 21 species (6 birds, 7 reptiles, 8 mammals). Mean number of individuals caught per cat Jan.- Nov. 1990 was 26.0 in the urban area; the rural cat caught 83 during this time. Extrapolation of the number of native vertebrates killed annually by all free-ranging cats reveals a large, but unrecognized and under studied, negative impact on the biota of the Virginia landscape.

HYDROPONIC VEGETABLE PRODUCTION USING FISH POND EFFLUENT WATER. Scott H. Newton & Jimmy Mullins, Va. Coop. Ext. Service, Va. State Univ., Petersburg, Va. 23803. Dwarf cherry tomatoes were produced hydroponically in a greenhouse using fish ponds as a source of water and nutrients in a production trial. Two groups of tomato plants were grown side-by-side in an experimental size greenhouse (75 ft. x 14 ft.) on Randolph Farm at Va. State Univ. One side of the greenhouse had plants which received the normal nutrient supplementation of fertilizers to produce maximum fruit yield. The other group of plants received only water from ponds which were being used to produce market size hybrid striped bass. Virginia State Univ. fish ponds are filled by pumping water from the Appomattox River. Raw river water is fairly representative of many ponds in Va., which are typically low in alkalinity and total hardness, but normal with regard to pH ranges. Tomato yield from plants that received pond water was 30% higher than from plants which received commercial fertilizer supplements. It appears that many Va. farm ponds may be used as a source of water for irrigation or hydroponics.

IMMUNOLOGICAL RESPONSES OF FISHES TO GLOCHIDIA OF FRESHWATER MUSSELS. Martin T. O'Connell, Dept. of Fisheries and Wildlife, Va. Polytechnic Inst., Blacksburg, Va., 24061-0321, & R.J. Neves, Va. Cooperative Fish and Wildlife Res. Unit, Blacksburg, Va., 24061-0321. The larval forms (glochidia) of most freshwater mussel species are obligate parasites to specific fish species. The immunological aspects of the host fish-glochidia interaction were studied using the Alabama rainbow mussel (Villosa iris) as the source of glochidia; host species was the rock bass (Ambloplites rupestris) and non-host fishes were common carp (Cyprinus carpio) and goldfish (Carassius auratus). Ouchterlony double-diffusion tests showed that both the host and non-host species expressed a specific humoral response to glochidial antigens after being artificially infested with the parasites. Further microagglutination tests were completed to compare titers of host and non-host fishes which were either uninfested, infested, or reinfested with glochidia. These tests showed that host and non-host species exhibit humoral responses of similar strengths to glochidia. In addition, fishes infested with glochidia had higher titers than uninfested fishes, and reinfested fishes had higher titers than both uninfested and infested fishes. This indicates that fishes express anamnestic responses to glochidia. (Supported by the Va. Dept. of Game and Inland Fisheries)

SMALL MAMMAL DIVERSITY IN HARDWOOD FOREST AND CLEARCUT HABITATS IN THE VIRGINIA PIEDMONT. John F. Pagels, Sandra Y. Erdle, and Kristen L. Uthus, Dept. of Biol., Va. Commonwealth Univ., Richmond, VA 23284; & Joseph C. Mitchell, Dept. of Biol., Univ. of Richmond, Richmond, VA 23173. In Cumberland County, 753 small mammals were captured representing 17 species. Captures included the uncommon Condylura cristata, and Oryzomys palustris, a species more at home in wetlands farther to the east. The most common species captured were Peromyscus leucopus, Zapus hudsonius, Cryptotis parva, Reithrodontomys humulis and Sorex longirostris. Diversity (H') was higher in the clearcuts, and overall captures were twice as great in the clearcuts as in the forest. Habitat generalists and edge/old field forms represented 64% and 33%, respectively, of the total captures in the forested habitats. In the clearcuts, however, the opposite was found: 61% were edge/old field forms, and 38% were generalists. Except for incidental captures, only Ochrotomys nuttalli and Sigmodon hispidus were confined to a given habitat type, i.e., the clearcuts. Other edge/old field forms, among them C. parva, R. humulis and Microtus pennsylvanicus, although captured in greater numbers in clearcuts, were also captured in the forested habitats, which indicates their ability to inhabit/move through less than desirable habitat when corridors of preferred habitat are not present.

THE EFFECTS OF HABITAT FRAGMENTATION AND LOSS ON DISMAL SWAMP MAMMALS. Robert K. Rose, Dept of Biological Sciences, Old Dominion University, Norfolk, Virginia 23529-0266.

In the 1890's, five new species of small mammals were described from the Great Dismal Swamp of Virginia and North Carolina. Since relegated to subspecies status, these taxa seem to have developed during the Holocene in association with the emergence of the Dismal Swamp. The Dismal Swamp, a forested wetland with a mosaic of vegetation types, formerly extended from the Chesapeake Bay to the Albemarle Sound but has been shrinking since the 18th Century due to efforts to drain the land for cultivation. More recently, much of the historic Dismal Swamp has been fragmented into subdivisions and industrial parks, and although more than 40,000 ha has been placed in a national wildlife refuge, habitat loss continues there through biological succession. Thus, the distinctive taxa of the region confront habitat loss via destruction, succession, or fragmentation, and for some, interbreeding with upland subspecies.

ONTOGENETIC CHANGES IN MICROHABITAT USE BY AGE-0 SMALLMOUTH BASS. Matthew J. Sabo & Donald J. Orth, Dept. of Fish. and Wild. Sci., Va. Polytechnic Inst. and St. Univ., Blacksburg, Va. 24061. Microhabitat use of age-0 smallmouth bass (Micropterus dolomieu) in the North Anna River, Virginia, was recorded throughout the period from May to August 1990. Larval smallmouth bass were initially restricted to microhabitats available within a defined brood site which was defended by an adult male. Dispersal habitats contained significantly lower mean water column velocities and more large cover than was available in brood sites. Larvae were more frequently observed occupying the entire water column in the dispersal habitats than in brood sites. As the summer progressed, age-0 bass continually moved into shallower habitats. Juveniles longer than 30 mm occupied habitats with higher mean water column velocities than 15 mm larvae occupied, and juveniles occupied higher nose velocities in August than they previously had occupied in July. Because availability of microhabitats did not change over the summer, we suspect that changes in microhabitat use were associated with predator avoidance behavior or changes in foraging tactics.

EFFECTS OF AERATION ON PRODUCTION OF HYBRID STRIPED BASS IN EARTHEN PONDS. Ephraim R. Seidman* & Scott H. Newton, Va. Coop. Ext. Service, Va. State Univ., Petersburg, Va. 23803. Aeration in fish ponds permits higher stocking rates, reduces water needs, and diminishes risk of mortality due to low dissolved oxygen levels. Phase II hybrid striped bass production trials have been completed without aeration at stocking rates of 20,000 and 40,000 fish/ha at Va. State Univ. In 1990, juvenile hybrid striped bass (mean weight 425 mg) were stocked at 60,000/ha in six 1,000 m² earthen ponds. Aspirator-propeller 1 HP aerators were placed in three ponds and operated daily from approximately 1700 to 0800 hrs. Growth rate and harvest weight in aerated ponds were greater than in non-aerated ponds. Mean growth rates were 0.69 and 0.40 g/day and mean harvest weights were 96.9 and 56.0 g for aerated and non-aerated ponds, respectively. Average gross pond production was greater (2,961 kg/ha) in aerated than in non-aerated ponds (2,215 kg/ha), although average survival was higher for non-aerated (67%) versus aerated ponds (52%). Mean Food Conversion Ratios were 1.47 and 1.63 for aerated and non-aerated ponds, respectively. These data suggest that production can be improved with the use of aerators when hybrid striped bass are cultured at 60,000/ha.

PHYLOGENETIC RELATIONSHIPS IN THE PROSIMIAN GENUS EULEMUR BASED ON A STUDY OF METACHROMISM. Douglas H. Shedd, Dept. of Biol., Randolph-Macon Woman's Col., Lynchburg, Va. 24503, & Joseph M. Macedonia*, Dept. of Zool., Univ. of California, Davis, Ca. 95616. The principle of geographic metachromism proposes that irreversible changes in the melanin banding patterns of hairs can be used to assess phylogenetic affinities among closely-related mammalian taxa. This study investigates metachromism in the genus Eulemur, using hair samples from animals at the Duke University Primate Center. Data gathered included the number of melanin bands present in hairs from species and subspecies comprising this genus, supplemented by information on melanin bandwidth, facial coloration, and hypertrichy. Our results support some existing phylogenies for the genus, but do not support the widely held belief that E. f. fulvus is ancestral to the entire genus.

THE IMPACT OF HUMAN ACTIVITIES ON THE UPLAND FORESTS OF WESTERN VIRGINIA. S. L. Stephenson, Dept. of Biology, Fairmont State Col., Fairmont, WV 26554, H. S. Adams, D. S. Lancaster Cmnty. Col., Clifton Forge, VA 24422, and M. L. Liptford, Virginia Natural Heritage Program, Richmond, VA 23219. Forest communities dominated by such species as red oak (*Quercus rubra*), chestnut oak (*Q. prinus*), white oak (*Q. alba*), and red maple (*Acer rubrum*) still cover large areas in the mountains of western Virginia. Although various human activities (e.g., lumbering operations, fires, and the clearing of land for agriculture) have had an impact upon these forest communities, the very limited data available from surveyor's records and other early accounts at least suggest that present-day forests are compositionally fairly similar to presettlement forests. Indeed, the most important change in composition that seems to have occurred is the almost complete elimination (at least from the forest canopy) of the American chestnut (*Castanea dentata*) by the chestnut blight. Prior to the blight, which was introduced into North America at the beginning of this century, chestnut was one of the most abundant trees in the upland forests of the mid-Appalachians. However, the potential for even greater change would seem to exist as a result of the spread of the gypsy moth (*Lymantria dispar*) into western Virginia, since oaks are among the tree species most susceptible to defoliation by this introduced insect pest.

CONTROLLED SPAWNING OF THE MARGINED MADTOM AND WHITETAIL SHINER. Joseph N. Stoeckel and Richard J. Neves, Virginia Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, Va. 24061. The margined madtom and whitetail shiner were used as surrogates in experiments to develop spawning techniques for the federally threatened and closely related yellowfin madtom and turquoise shiner. Experiments to induce spawning naturally or with injections of luteinizing hormone releasing hormone analogue (LHRHa) + pimozone administered over an extended period were unsuccessful. Females failed to ovulate and aggression of whitetail shiner males often resulted in mortality of other whitetail shiners. Hormone injections immediately after capture can induce ovulation in whitetail shiner females. Greater than 20% of whitetail shiner females ovulated following injections of LHRHa + domperidone (dom), human chorionic gonadotropin (hCG) + carp pituitary extract (CPE), or injections of LHRHa + dom followed by hCG + CPE. Higher fertilization rates were obtained with domesticated fish than wild fish, and when spawning occurred within twenty-four hours following 2 hormonal injections. Large tanks are requisite to holding whitetail shiners in captivity. Maturation, but not ovulation, of margined madtom ova was achieved following injections of either LHRHa + dom or hCG + CPE. Motile sperm was not observed in margined madtom males. Satisfactory ovarian development in captive fish was achieved with a diet of commercial flake food for whitetail shiners, and self-manufactured moist pellet for margined madtoms. (Supported by the US Fish and Wildlife Service and the Virginia Department of Game and and Inland Fisheries).

HISTOCHEMICAL LOCALIZATION OF HYALURONIC ACID DURING EARLY CHICK ORGANOGENESIS. John K. Straumann, and Carolyn M. Conway, Dept. of Biol., Va. Commonwealth Univ., Richmond, Va. 23284, Chick embryos were obtained at various stages of development (72, 96, and 120 hrs), fixed, embedded in glycol methacrylate, and sectioned at 3 μ m. A biotinylated probe specific for hyaluronic acid (followed by streptavidin-peroxidase complex) was used to localize regions of the embryos containing free hyaluronate. A number of parameters including method of fixation, embedding medium used, probe concentration, and incubation temperature and time, enzymatic digestion of sections, and streptavidin-peroxidase concentration and incubation time. These modifications were compared to see which permitted the greatest penetration of the probe, thus allowing satisfactory staining and identification of the extracellular regions containing hyaluronic acid. The very best staining resulted from fixation using the AMeX method, embedding in Immuno-Bed, incubation with probe at 37°C, and increased streptavidin-peroxidase concentration. Using this technique, hyaluronic acid was localized in a variety of regions throughout the developing embryo. In some areas, there was no staining whatsoever while other areas differed from diffuse background staining to heavy localized staining. The regions that had the most interesting staining patterns were the developing heart, chondrocytes, and mesenchyme in the region of the developing brain. These regions also seemed to vary in staining pattern and intensity for the different developmental stages observed. Our results support the theory that each cell's contribution to the extracellular matrix is different and that the changing extracellular environment may be guiding the development of cells into different tissues and organs.

REDUCTION OF REPRODUCTION AT VARYING DENSITIES IN NATURAL POPULATIONS OF WHITE-FOOTED MICE (PEROMYSCUS LEUCOPUS NOVEBORACENSIS). C. R. Terman, Lab. of Endo & Pop. Ecol., Biology Dept., Col. of William and Mary, Williamsburg, Va. 23185. White-footed mice on an 11 ha area were studied monthly with 600 live traps and 254 nest boxes from 1983-1989. Location, sex, age, body weight, and reproductive condition of individual animals were recorded. Data from nest boxes were consistent with those from trapping, but rarely did more than 40% of the population occur in the nest boxes and use declined to less than 10% of the population during the summer. Trappability was greater than 90%. The number of adults varied from 22.9/ha in March 1983 to 0.3/ha in November 1984. Significantly more males than females were captured during the study. In 58 of 72 months, a smaller % of males than females was reproductively mature. The proportion of adults reproductive during May, June, and July was significantly lower than during February - April and August - October. Factors producing this significant retardation of reproduction are unknown. (Supported by a William and Mary Faculty Summer Research Grant and by the Thomas F. and Kate Miller Jeffress Memorial Trust.

EFFECTS OF LOW-INTENSITY URBAN DEVELOPMENT ON THE STRUCTURE AND FUNCTION OF A STREAM FISH ASSEMBLAGE. L. Alan Weaver & Greg C. Garman, Dept. of Biol., Va. Commonwealth Univ., Richmond, Va. 23284. The recent effects of increased imperviousness of the watershed, removal of riparian vegetation, and stream channel modification on a Piedmont stream fish assemblage were assessed in Tuckahoe Creek, Va. Data collected in 1958 prior to extensive watershed disturbance allowed for the testing of several hypotheses concerning the ecological effects of low-intensity urban development. Total fish species richness declined from 31 in 1958 to 26 in 1990. The number of species lost from each of six sites ranged from two to 11. Bluegill (Lepomis macrochirus) replaced johnny darter (Etheostoma nigrum) as the numerically dominant species (all sites). Other hypothesized taxonomic shifts were documented for the period between 1958 and 1990. The diets of four selected species (bluegill, johnny darter, common shiner (Notropis cornutus), & bluehead chub (Nocomis leptocephalus) were evaluated for changes in composition, niche breadth, and utilization of terrestrial arthropods. Terrestrial prey comprised 5.3% of the bluegill diet (all sites) in 1958 which increased to 9.1% for 1990.

HISTORIC TRENDS IN WETLAND PROTECTION IN THE STATE OF VIRGINIA. Harold J. Wiggins, U.S. Army Corps of Engineers, Norfolk District, Fredericksburg Field Office, 10703 Courthouse Rd., Suite 270, Fredericksburg, Va. 22407. Recent Virginia state legislation involving inland non-tidal wetland area brings greater coordination between federal, state and local jurisdictions. The Chesapeake Bay Preservation Act of 1988 as mandated by state law compels local planning departments to recognize and identify non-tidal wetland area as Resource Protection Areas (RPA's) and Resource Management Areas (RMA's). The Virginia State Water Control Board has recently asserted its certification of authority for discharges exceeding 1 acre in headwaters and isolated waters.

As a result of an interagency agreement wetland area can be assessed and delineated to concur with a unified definition. This federal definition has brought greater jurisdictional regulation to wetland habitats in Virginia. Palustrine, forested, broad leafed, seasonally saturated wetlands (PF01A's) have received greater protection as a result of the unified federal definition. The Norfolk District of the Army Corps of Engineers has opened four new field offices in Virginia in early 1991. Greater Corps involvement with more field offices will minimize and regulate wetland losses.

LAND USE, ENVIRONMENT, AND THE REGENERATION OF PINUS PUNGENS. Charles E. Williams, The Nature Conservancy, 1110 Rose Hill Dr., Suite 200, Charlottesville, VA 22901. Table mountain pine, Pinus pungens Lamb., is a disturbance dependent conifer endemic to the central and southern Appalachian Mountains. Although generally widespread, recent evidence suggests that P. pungens may be declining in parts of its range due to fire suppression. I present a three phase conceptual model which suggests that changes in the areal extent of P. pungens is the result of human land use in conjunction with environment. Presettlement phase: prior to European settlement of the Appalachians, P. pungens populations are mainly restricted to xeric ridgetops and rock outcrops, but periodically spread into other parts of the landscape following lightning-generated fires. Expansion phase: after settlement, P. pungens populations expand into more mesic sites with increased clearing and burning of forests. Decline phase: changes in land use and suppression of fires result in the decline of P. pungens, and the increase of tolerant hardwoods, on mesic sites; unfavorable disturbance regimes and competition with hardwoods cause P. pungens populations to retract to xeric sites.

Botany

DENDROECOLOGY OF RED SPRUCE (PICEA RUBENS) IN THE SOUTHERN APPALACHIANS. H. S. Adams, D. S. Lancaster Cmnty. Col., Clifton Forge, VA 24422 and S. L. Stephenson, Dept. of Biology, Fairmont State Col., Fairmont, WV 26554. Dendroecological (tree-ring) analysis of increment growth cores collected from red spruce (Picea rubens) trees at a number of localities in Virginia, West Virginia, Tennessee, and North Carolina indicates that a growth-trend decline has occurred since the 1960s. This decline is similar to that reported for this species in the northeastern United States during the same time period. Tree-ring data we have obtained for other species of conifers in the same general region and elsewhere strongly suggest that the recent decline in growth of red spruce (and perhaps for the two species of fir [Abies balsamea and A. fraseri] commonly found as associates of red spruce) is both anomalous and unique. Undoubtedly, research efforts over the next decade will provide a clearer picture of the changes occurring within the red spruce forest type in the southern Appalachians. These data should help answer the question as to whether the general health of red spruce is seriously declining.

THE STATUS OF POPULATIONS OF HELENIUM VIRGINICUM BLAKE (ASTERACEAE), A VIRGINIA ENDEMIC SNEEZEWEED. Nancy E. Van Alstine, Virginia Dept. of Conservation and Recreation, Div. of Natural Heritage, 203 Governor St., Suite 402, Richmond, Va. 23219. Helenium virginicum is a Virginia endemic plant and state endangered species known only from seasonally wet sinkhole ponds and meadows in Augusta and Rockingham counties on the west side of the Blue Ridge. In 1990 a survey was conducted to reassess the known populations and search for new populations at sinkhole ponds identified from aerial photos and maps. H. virginicum populations were found at eleven out of 16 previously known population sites and at two out of 22 new sites searched. Two of the revisited sites without current populations had suffered major drainage changes. Only three of the revisited populations and the two new populations were in relatively undisturbed sinkhole ponds; seven were in habitats disturbed by grazing, mowing, or drainage control. Some of these disturbed sites supported the largest populations, but their long-term survival could be threatened by increasing residential land use and drainage control. The site of one of the revisited populations, although privately owned, is managed as a preserve by The Nature Conservancy. Three of the population sites, located within George Washington National Forest, are included within lands proposed as Special Management Areas.

WAS VIRGINIA A PLEISTOCENE REFUGIUM FOR SHALE BARREN ENDEMICS?

Rodney L. Bartgis, Maryland Natural Heritage Program, Tawes State Office Building, Annapolis, Md. 21401. Previous researchers had compared the current distribution of plants endemic to the central Appalachian shale barrens with the suspected evolutionary history and dispersal mechanisms of each species, but no correlative patterns were determined. Based on a more complete survey of the shale barren flora than was previously available, the strict endemics have two distributional patterns: some species are widespread throughout the shale barren region while other species have a distribution restricted to the southern half of the region. The latter species typically have distributions with a focus in the James River watershed of Virginia, but show differential emigration patterns into adjacent watersheds. It is suspected that the observed patterns indicate that currently widely distributed species were probably widespread during the last glacial maximum, but that climatic events restricted the other endemics southward into a refugium centered in the James River watershed.

ESTABLISHMENT OF *PUCCINIA CARDUORUM*, AN EXOTIC RUST PATHOGEN OF MUSK THISTLE, IN VIRGINIA.

A. B. A. M. Baudoin, Dept. of Plant Pathol., Physiol. and Weed Sci., R. G. Abad, and L. T. Kok, Dept. of Entomol., Va. Polytechnic Inst. & State Univ., Blacksburg, Va. 24061. A strain of a rust fungus (*Puccinia carduorum* Jacky) from Turkey was released in 1987 in field plots near Blacksburg, VA, to be evaluated as a biological control agent for musk thistle (*Carduus thoermeri* Weinmann). Musk thistle plants were inoculated with urediniospores of the fungus both in the fall and spring. Small numbers of rust pustules were found only in fall-inoculated plots in late March or early April, prior to spring inoculations, indicating that the fungus had overwintered. Disease development and spread was limited during the rosette stage; in non-inoculated plots, rust was generally not detected until May. In each of 3 years, disease became severe only when the plants bolted. The rust was detected only a few hundred meters from the release site in 1988, but in 1989 traces of rust were detected at naturally occurring musk thistle stands up to 7 km away. In 1990, severe rust was detected at these distant sites during flowering, suggesting that the pathogen is now probably established in western Virginia. (Supported in part by a cooperative grant from the Foreign Disease and Weed Research Unit, USDA-ARS.)

MICROSCOPIC ANALYSIS OF ROOT EMERGENCE IN LEMNA GIBBA.

Catherine A. Boyd, M. H. Renfro, P. T. Neilsen, and J. Winstead, Dept. of Biol., James Madison Univ., Harrisonburg, VA 22807. All roots of *Lemna gibba* are considered to be adventitious in origin, as there is no radicle present in the mature embryo. Roots originate in the subepidermal layer of the ventral surface of the frond. The epidermis covers the developing root primordium forming a sheath. The sheath is penetrated by the root cap, which in *Lemna* is well developed and persistent during the life of the root. As the root elongates the sheath remains as a persistent feature at the base of the root. The site of emergence appears to be morphologically determined.

HARDWOOD FORESTS IN THE COASTAL PLAIN OF VIRGINIA EAST OF THE SUFFOLK SCARP. Penny Cazier and Stewart Ware, Dept. of Biol., Col. of Wm. and Mary, Williamsburg, VA. Twenty-three predominantly hardwood forest stands on low, level uplands in the eastern Coastal Plain were sampled and their composition analyzed for correlation with edaphic factors. In five stands the leading dominant was Liquidambar styraciflua, and Acer rubrum led in four stands. These species were found on all remaining sites, and were major associates where Liriodendron tulipifera was important. Quercus alba was usually associated with Pinus taeda in wetter sites, and sometimes with Fagus grandifolia. In two stands the leading dominant, Q. nigra, was associated with Q. alba and P. taeda. Stands with high importance of Q. pagoda usually contained Q. michauxii and sometimes Q. phellos. Quercus laurifolia was the leading dominant in two stands containing Nyssa sylvatica var. biflora, L. styraciflua, and A. rubrum. The poorly drained non-alluvial sites sampled in this study contain a mixture of southern swamp species and Southern Mixed Hardwood Forest species.

FOREST COMPOSITION, ENVIRONMENTAL VARIABLES, AND LAND USE HISTORY IN THE NORTHERN NECK OF VIRGINIA. Elizabeth E. Crone and Stewart A. Ware, Dept. of Biol., Col. of Wm. and Mary, Williamsburg, VA. Twenty-four forest stands in Westmoreland State Park in the Northern Neck of Virginia were quantitatively sampled. Vegetation ordination (DCA) separated the stands into four distinct groups. Group I was dominated by Quercus prinus and Q. alba and was located on the left (low pH, low Mn, high % clay) to center portions of the first DCA axis. Group II was characterized by abundant Fagus grandifolia and fell in the lower (high slope, high Ca, north-facing) portion of the ordination. Group III was characterized by Liriodendron tulipifera and the absence of I.V. > 10% for oaks or beech and was located at the right (high pH, high Mn, low % clay) side of the ordination. Group IV consisted of two stands at the extreme upper right corner of the ordination (high Ca, flat) that were dominated by Q. falcata. Acer rubrum was also important throughout the study area. Most of the stands in the highly dissected study area fell into Group I, but it is possible that the prevailing vegetation of the Northern Neck, if fully forested, would be more like the stands in Group IV. Most of the Northern Neck is topographically more similar to the level, inland Group IV stands.

RESIDENT ENDOPHYTIC FUNGAL POPULATIONS IN STRESSED AND NON-STRESSED SCARLET OAK (Quercus coccinea) IN THE JEFFERSON NATONAL FOREST AT BLACKSBURG, VA. Gonzalo Guevara, R. J. Stipes and D. Wm. Smith, Dept. Plant Pathol./Phyiol./Weed Sci. & Forestry, Virginia Tech, Blacksburg 24061. A survey for endophytic fungi in living, standing, stressed or non-stressed scarlet oak trees was conducted. Fungi were aseptically isolated from increment samples placed onto antibacterial potato-dextrose agar at 25C. 26 samples from Poverty Creek (non-stressed) and 23 from Brush Mountain (stressed) trees were studied. 50% of the samples from the non-stressed trees were sterile, 23% yielded Paecilomyces aff. variotii, and 27% were colonized by numerous other fungi. On the other hand, 100% of samples from stressed trees (Brush Mountain) were colonized by fungi; 74% yielded P. aff. variotii, and 26% other fungi. Other less frequently observed fungi were Stereum aff. complicatum, S. ostrea, Schizophyllum commune, Hymenochaete sp., Poria sp., Hypoxylon atropunctatum and H. punctulatum. Attempts to find Graphostroma platystoma and Eutypa spinosa from standing trees were unsuccessful. These findings support our hypothesis that cull (stressed) trees in woodlots commonly used by shiitake farmers are poor choices for shiitake logs because they may contain aggressive competitors of Lentinus edodes, the shiitake mushroom fungus.

TEMPERATURE AND pH GROWTH OPTIMA ON LABORATORY MEDIA OF Lentinus edodes (SHIITAKE MUSHROOM) AND THE MAJOR SHIITAKE LOG "WEED FUNGI," Graphostroma platystoma and Eutypa spinosa. Gonzalo Guevara and R. J. Stipes, Dept. Plant Pathol., Physiol. & Weed Sci., Va Tech, Blacksburg 24061. Temperature (5-40C) and pH (3.5-7.0) growth ranges were investigated for G. platystoma and E. spinosa ("weed fungi"), and L. edodes (shiitake) VT17; glucose-yeast extract agar, and glucose-yeast extract-wood decoction liquid media were used for these tests, respectively. Mycelial growth, measured linearly or as dried biomass, was the criterion used. The cardinal temperatures for growth of G. platystoma were 10C (min.), 25-28C (opt.), and 32C (max.). The cardinal temperatures for growth of E. spinosa were 15C (min.), 28-32C (opt.) and ?C (max.). The cardinal temperatures for growth of L. edodes were 5C (min.), 25C (opt.), and 32C (max.). The optimum pH ranges for growth of G. platystoma, E. spinosa and L. edodes, respectively, were 6.5-7.0, 5-7, and 3.5-4.5. These findings suggest that L. edodes is acidophilic, and therefore would likely grow well in oak logs with highly acidic sapwood. The data further indicate that shiitake log inoculation should be done during the late winter/early spring when temperatures are lower, and therefore more suitable for the growth of L. edodes and less suitable for the growth of the "weed fungi."

COMPARATIVE WHITE ROTTING POTENTIAL OF THE SHIITAKE MUSHROOM (Lentinus edodes) FUNGUS AND THE TWO MAJOR SHIITAKE LOG "WEED FUNGI" IN THE VIRGINIA HIGHLANDS. Gonzalo Guevara, J. G. Palmer and R. J. Stipes. Dept. Plant Pathol., Physiol. & Weed Sci., Virginia Tech, Blacksburg, VA 24061. The comparative maximum decay potential of pin oak (Quercus palustris) sapwood by Lentinus edodes (LE) and the two major shiitake log "weed fungi" (Graphostroma platystoma (GP) and Eutypa spinosa (ES)) was evaluated. We used the ASTM (Amer. Soc. for Testing & Materials) method in which weight losses of inoculated wood blocks were determined by monitoring pre- and post-rot values. Moisture and temperature were carefully regulated during the experimental period. GP and ES caused 20% and 16% losses, respectively, while LE strains VT17, U8, W4 and WG induced respective weight losses of 16%, 13%, 19% and 16%. A control standard, Trametes versicolor, yielded a 16% loss, while a non-inoculated control remained changeless in weight. The comparable weight loss induced by these competitive weed fungi found in shiitake logs supports our hypothesis that these weed fungi are major deterrents to long-term fruiting performance of logs of Virginia shiitake farmers. A number of companion studies on the shiitake production problems are in progress, and are being presented at this conference.

SENSITIVITIES OF LENTINUS EDODES, GRAPHOSTROMA PLATYSTOMA AND EUTYPA SPINOSA TO FUNGICIDES. Gonzalo Guevara and R. J. Stipes, Dept. Plant Pathol., Physiol. and Weed Sci., Virginia Tech, Blacksburg 24061. Shiitake growers in VA are experiencing considerable losses of the fruiting life of oak logs due primarily to competing Ascomycetes ("weed fungi") present in tree tissues before felling. We surveyed several shiitake farms, and although the fungal flora differed among them, the predominant colonizing fungi were identified as Graphostroma platystoma and Eutypa spinosa. The fungitoxicity tests showed that these "weed fungi" are sensitive to Arbotect 20S and Lignasan BLP fungicides at acceptably low concentrations, while Lentinus edodes (shiitake fungus), VT17, was not. G. platystoma was inhibited at 10-1000 ug/ml by both fungicides, and E. spinosa was inhibited at 1.0-1000 ug/ml with both fungicides, while L. edodes VT17 was not. We used standard potato-dextrose agar in these tests, and sensitivity was determined by mycelial growth inhibition. These findings suggest that shiitake farmers might be able to control "weed fungi" by soaking their logs in these fungicides previous to inoculation with L. edodes, while doing no harm to L. edodes. If these fungicides were labeled for this use, residue analyses must be done on the mushroom produced by treated logs, with tolerance limits established.

GENETIC UNIFORMITY OF EL ARBOL DEL TULE (THE TULE TREE). Gustav W. Hall, Dept. of Biology, Col. of William and Mary, Williamsburg, VA 23185, George M. Diggs, Jr.*, Dept. of Biology, Austin Col., Sherman, TX 75090, Douglas E. Soltis* and Pamela S. Soltis*, Dept. of Botany, Washington State Univ., Pullman, WA 99164-4230. An electrophoretic analysis of enzymes was conducted on leaf material from each of eight major segments of the Tule Tree, an immense specimen of Montezuma Bald-cypress, Taxodium mucronatum, from Oaxaca, Mexico. This quite famous tree, some 36 m. (118 ft.) in girth, has been variously interpreted as a single enormous individual or as a natural grafting of several individuals. For comparison, two nearby conspecific individuals were also analyzed electrophoretically. That all segments of the Tule Tree were heterozygous for shikimate dehydrogenase-2, and the neighboring trees both homozygous, is consistent with the hypothesis that the Tule Tree is one genetic individual. The literature on the Tule Tree, including the controversies over its age and whether it was personally observed by Cortes and by Humboldt and Bonpland, is reviewed.

PHYTOPLANKTON COMPOSITION AND ABUNDANCE IN A POLLUTED RIVER SYSTEM: THE ELIZABETH RIVER. Mary F. Hanover and H.G. Marshall, Dept. Biological Sciences, Old Dominion University, Norfolk, Va. 23529-0266. The main branch of the Elizabeth River is located in Norfolk-Portsmouth port complex in Virginia. The Elizabeth River has been characterized as a highly polluted system, where industrial wastes, petroleum products and other contaminants from port operations have contaminated the waters and its substrate. Our studies indicated an abundant and diverse phytoplankton component is present, consisting of mainly neritic species common to the lower Chesapeake Bay. Phytoplankton concentrations are at 10^6 cells/l, with picoplankton levels at summer highs of 10^8 cells/l. Growth maxima occur in spring, summer and fall, with higher concentrations associated with downstream stations, except for picoplankton. Cell concentrations were generally higher below the pycnocline for diatoms, silicoflagellates and cryptomonads. One toxin producing dinoflagellate was present, but no blooms were noted during a 12 month study period. Supported by the Virginia Water Control Board.

TAXONOMIC STUDIES OF NEOTROPICAL AMANOA (EUPHORBIACEAE). W. John Hayden, Dept. of Biol., Univ. of Richmond, Richmond, Va. 23173. Recent study of neotropical species of the genus Amanoa has resulted in several taxonomic adjustments. Four new species, A. congesta, A. gracillima, A. nanayensis, and A. neglecta have been published, largely from materials that had been erroneously referred to A. quianensis, the most abundant and widespread species in the genus. Lectotypes have been selected for A. caribaea and also for A. quianensis, in which the selection was complicated by inclusion of one of the new species, A. neglecta, among the presumed syntypes. Amanoa robusta Leal was discovered to be a later homonym; this species has been renamed A. sinuosa. Delimitation of new and previously named species is supported by pollen and foliar epidermal sclereids in addition to features of gross morphology.

Convergence In The Early Evolution Of Megaphyllous Leaves. Stewart A. Hill and Stephen E. Scheckler, Dept. of Biol., V.P.I. & S.U., Blacksburg, Va. 24061. Megaphyllous leaves are believed to have evolved independently in several groups descended from trimerophytes (an Early to Middle Devonian group of plants). At least two of these descendent lines, leading to modern gymnosperms and ferns respectively, pioneered similar morphological strategies for light reception. By the Late Devonian, both early gymnosperms and pre-ferns had derived a frond-style of megaphyll, with bifurcated pinnae bearing laminated pinnules of the Sphenopteris type. That the fronds of these two groups were independently achieved, however, is shown by differences in the basic architecture of their fronds. Nonetheless, the striking similarity between early gymnosperm and pre-fern fronds has led to some confusion with respect to the attribution and evolutionary analysis of fossilized frond fragments from Late Devonian to Carboniferous aged rocks. Our recently discovered Late Devonian plant with Sphenopteris like foliage demonstrates the difficulty of assessing the affinities of such fossils, while exemplifying their importance to the evolutionary analysis of extinct plants.

LIGHT RESPONSE OF THE SHALE BARREN ENDEMIC *ERIOGONUM ALLENI* TO SHADE TREATMENTS. Suzanne M. Hill, Biology Dept., Virginia Polytechnic Institute and State University., Blacksburg, VA 24061. Shale barrens are unique habitats occurring throughout the Appalachians and range from southwestern Virginia to southern central Pennsylvania. Although sparsely vegetated overall, shale barrens support a community of endemic, or near endemic, plant species. Since shale barrens have a relatively open canopy, the herbaceous layer is routinely subjected to full sunlight; a marked difference from the environment experienced by herbs in surrounding deciduous forests. It has been hypothesized that the shale barren endemic *Eriogonum allenii* is an obligate heliophyte (a high light requiring plant). This was tested in the field and laboratory by manipulating total irradiance. *E. allenii* plants were maintained under moderately (47 %) and heavily (73 %) shaded conditions. Photosynthesis was monitored, and light response curves were obtained. *E. allenii* has, thus far, demonstrated characteristic responses of a high light adapted plant.

COMPARISONS OF STOMATA AND CUTICLE DURING IN VITO CULTURE AND ACCLIMATIZATION OF *BETULA PENDULA* ROTH.- Joressia A. Jamison, M. H. Renfroe and J. Winstead, Dept. of Biology, James Madison Univ., Harrisonburg, VA 22807. The acclimatization or hardening-off of European white birch (*Betula pendula* Roth.) grown in vitro was studied using scanning electron microscopy. Comparisons were made among leaves of plants in culture, plants at time of transfer from in vitro conditions, plants one week after transfer to soil, plants acclimated from in vitro conditions, and seedlings. Leaves of plants in vitro had the largest stomata and the least amount of cuticle development. Leaves from acclimated plants were almost equal to seedlings in stomatal length, stomatal density, and cuticle development. Leaves from plants at time of transfer had the highest stomatal density. Generally, cuticular wax was thicker on the adaxial side of the leaf while stomatal density was greater on the abaxial side of the leaf in all observed groups.

THE TAXONOMIC SIGNIFICANCE OF HAIRS ON GOLDENRODS *EUTHAMIA* AND *SOLIDAGO*. Miles E. Johnson, Dept of Biol., Va. Commonwealth Univ., Richmond, VA 23284-2012. Hairs (trichomes) from leaves, stems and achenes of *Solidago* and *Euthamia* from Virginia are investigated with scanning electron microscopy. Although these genera have been lumped in many regional manuals, the trichomes are notably different in morphology between genera and support trichome morphology supports the current concept that these genera are separate entities. Trichomes from *Solidago* are simple, uniseriate and multicellular with variation noted in length of trichome and in the number of cells per trichome. Species grouped by Cronquist (Vascular Flora of the Southeastern United States, 1980) show similarities in trichome morphology. Trichomes from achenes are uniform and offer little taxonomic value. This research was supported by VCU and the Virginia Academy of Science Virginia Flora Committee.

A PHYLOGENETIC ANALYSIS OF THE GENUS PRUNUS (PRUNOIDEAE, ROSACEAE). John G. Kell and Khidir Hilu, Dept. of Biol., Virginia Polytechnic Inst. & State Univ., Blacksburg, Va., 24061. Phylogenetic relationships among the fifteen Sections, representing all five subgenera (Laurocerasus, Padus, Cerasus, Prunophora, and Amygdalus), of Prunus are investigated using cladistic analysis of morphological and chemical data. Fourteen cladograms of equal length and with a consistency index of 0.60 were produced. The cladistic relationships among sections in the consensus cladogram are not consistent with the monophyly of two of Rehder's five subgenera,; both subgenus Cerasus and subgenus Prunophora are paraphyletic. The three monophyletic groups in the genus are Laurocerasus, Padus, and the combination of Cerasus, Prunophora, and Amygdalus. However, relationships of sections within Prunophora and Cerasus are not fully resolved and need further study. The subgenus Laurocerasus is the sister group to the rest of the genus.

GEOGRAPHIC PATTERNS IN FOREST COMMUNITY COMPOSITION IN THE RIDGE AND VALLEY PROVINCE, VIRGINIA AND WEST VIRGINIA. David M. Lawrence, Institute of Geographical and Geological Sciences, George Mason University, Fairfax, VA 22030. The upland forest communities on Massanutten Mountain, Virginia, and North Fork Mountain, West Virginia, were sampled in an effort to discern geographic patterns in forest community composition in the Ridge and Valley Province. The forest communities on Massanutten Mountain, at the eastern extreme of the region, were found to be more xeric in character than those on North Fork Mountain, at the western extreme of the region. The influences of a variety of environmental factors are suggested to account for the differences among forest communities on the two mountains.

DYNAMICS OF SIZE DISTRIBUTION PARAMETERS IN JUVENILE LOBLOLLY PINE (PINUS TAEDA L.) STANDS. Jiping Liu and Harold E. Burkhart, Dept. of Forestry, Va. Polytechnic Institute & State Univ., Blacksburg, VA 24061-0324. Spacing trials have been established at four locations in the Piedmont and Coastal Plain regions of Virginia and North Carolina. The ground-line diameter (GD), later diameter at breast height (DBH), total height (TH), and crown height (CH) of each tree have been measured annually since 1983. Based on statistical analysis on the data, the parameters examined, such as coefficient of variation (c.v.), Gini coefficient (g.c.) and skewness, of tree size distributions were found to be significantly correlated with stand age and with number of trees per unit area. Some subtle differences were found among the distributions. The c.v. and g.c. of CH decreased with both age and density ($p\text{-value} < .0001$). However, those of GD, DBH and TH decreased with age, but increased with density. Competition resulted in increased negative skewness. The kurtosis values were not found to be significantly different among densities, but kurtosis generally increased with stand age, ranging from zero or slightly negative for very young stands to a positive value for older stands. Tests of normality were applied for distributions of these variables. Although all variables were approximately normally distributed, the trends in p-values over time varied among them.

EFFECTS OF PARTIAL DEFOLIATION ON FRUITING AND SEED SET IN FOUR SPRING WILDFLOWER SPECIES. Marion Blois Lobstein, NVCC-Manassas Campus, Manassas, VA 22110 & L. L. Rockwood, Dept. of Biol., George Mason Univ., Fairfax, VA 22030. In order to determine the effect of defoliation on subsequent reproduction in perennial herbaceous plants, portions of leaves were experimentally removed from four species of understory spring-flowering plants in Loudoun County, VA in April 1990. Fruits were collected in May and June from control and experimental plants. 50% defoliation had no significant effect on the number of plant fruiting in Jeffersonia diphylla, Sanquinaria canadensis, or Erythronium americanum. 100% defoliation did significantly effect the percent of plants fruiting in S. canadensis. The percent of Trillium sessile plants fruiting was not effected by either 33% or 67% defoliation. In fact, defoliation short of 100% had no significant effect on any measured aspect of seed or fruit production in E. americanum, T. sessile, or S. canadensis with the exception of S. canadensis where there was a significantly higher number of undeveloped embryos in 50% defoliated plants versus control plants in which no leaves were removed. Aspects of fruit and seed production measured in control versus defoliated plants were: percent fruiting, mean number of seeds per fruit, mean fruit mass, mean seed mass per fruit, and mean mass per seed.

EFFECTS OF ELAIOSOME REMOVAL ON GERMINATION OF SEEDS: A RESEARCH SUMMARY. Marion Blois Lobstein, Dept. of Biol., N.V.C.C.-Manassas Campus, Manassas, VA 22110 & L. L. Rockwood, Dept. of Biol., George Mason Univ., Fairfax, VA 22030. Since 1984 the authors have investigated the hypothesis that elaiosome removal might enhance the germination rate of seeds from ant-dispersed plant. In the past two years (1989-90, 1990-91) the authors have standardized their technique which has produced more consistant results. In brief, intact seeds and seeds in which elaiosomes have been removed have been placed on foam pads in petri dishes. The seeds have then been incubated for 3-4 months at 27.5 C and 15 C for 12 hours each per day, for 3 months at 20 C and 10 C for 12 hours each per day, 3-4 months at 5 C for 24 hours per day, and back to 20 C and 10 C for 12 hours each per day to simulate seasonal changes for summer, fall, winter, and spring. This treatment regime has produced high germination rates for Sanquinaria canadensis, Asarum canadense, Jeffersonia diphylla, and Viola striata. Only in S. canadensis did elaiosome removal enhance germination rates significantly for the last two years at rates of 56.7% and 46.7% versus 23.3% and 13.3% respectively ($p < 0.001$). For both years germination rate of Dicentra cucullaria and Trillium sessile were low at 3-4% and 0% respectively for both treated and control seeds.

ON THE TRAIL OF FERNALD II. THE INTERDUNAL WETLANDS OF VIRGINIA BEACH. J. Christopher Ludwig, Department of Conservation and Recreation, Division of Natural Heritage, 203 Governor Street, Suite 402, Richmond, Va. 23219. During the late 1930's and early 1940's, eminent Botanist, Merritt Lyndon Fernald explored the flora of Virginia's southeastern corner, looking for new, unusual, and rare plant species. During his early explorations, he described the unusual flora of numerous wetlands between dunes along the coast of the Atlantic Ocean and the Chesapeake Bay in what is now Virginia Beach City. Fernald's wetlands were revisited as well as additional areas where this flora may persist. Results of exploration into the interdunal wetland flora is presented emphasizing the occurrence and status of the region's rare plant species.

STEM PHOTOSYNTHESIS: AN ADAPTATION TO STRESSFUL ENVIRONMENTS. Erik T. Nilsen, Department of Biology, VPI and State University, Blacksburg, Va. 24061. Stem photosynthesis is recognized as an adaptation which increases carbon gain for plants in stressful environments. Stem chloroplasts have a reduced capacity compared to leaves on the same plant. In some cases, stems transpire without positive carbon gain (Soybean). In the case of Spartium junceum stems have a higher temperature optimum, lower quantum yield, and greater resistance to atmospheric or soil induced drought. In addition, during nitrogen limitation stem photosynthesis is favored over leaf photosynthesis. Stems can contribute about 50% of a plants daily carbon gain, particularly during stressful conditions.

DIAGNOSTIC CHARACTERISTICS OF MAFIC WETLAND VEGETATION IN VIRGINIA. Thomas J. Rawinski, Va. Dept. of Conservation and Recreation, Div. of Natural Heritage, 203 Governor St., Suite 402, Richmond, Va. 23219. Certain wetland soils containing high magnesium relative to calcium can be described as mafic, and one plant species, Sanguisorba canadensis, is especially diagnostic of these wetland environments and their vegetation in Virginia. The Braun-Blanquet approach to community classification and interpretation was used to identify two mafic wetland plant communities, the Sanguisorba canadensis - Parnassia grandifolia Association and the Sanguisorba canadensis - Scirpus cyperinus Association. These Associations are placed within a provisional classification of soligenous wetland vegetation. A harsh edaphic environment, as suggested by low calcium:magnesium ratios, best explains the stunted condition of certain woody species and the occurrence of so many rare plants in these communities. A limited literature review suggests that Sanguisorba canadensis is also diagnostic of mafic wetland vegetation beyond Virginia.

EARLY DEVELOPMENT OF ADVENTITIOUS SHOOTS IN AFRICAN VIOLET. Michael H. Renfro, Dept. of Biol., James Madison Univ., Harrisonburg, VA 22807. African violet leaf explants were cultured on a shoot induction tissue culture medium. Explants were observed to thicken at the base in or just above the medium surface. Cut sections revealed that increased meristematic activity in the spongy parenchyma layer of the mesophyll coincided with the thickening and preceded the appearance of organized meristems at the epidermal level. Leaf primordia enlarged quickly and developed both glandular and septate trichomes at early stages. Well-developed stomata were also visible on leaf primordia indicating that differentiation from protoderm to epidermis occurs very quickly during leaf primordia development in African violet.

NEW HOSTS FOR GRAMINICOLOUS FUNGI IN VIRGINIA: 1989-1990. Curtis W. Roane and Martha K. Roane. Dept. of Plant Pathology, Physiology & Weed Science, VPI&SU, Blacksburg, Va., 24061. Study of fungi on grasses in Virginia has been confined mostly to cereals, turf and pasture species. In 1989-90 on about 140 grass specimens we identified about 85 fungi. Listed are some fungi previously known from Virginia and some new hosts for them. The list is cryptic whereby H=host, U=new host for United States, V=new host for Virginia, and P=previously known on a Virginia host. Colletotrichum graminicola, anthracnose cereals, 24H (16U, 7V, 1P); Ascochyta sorghi, 18H (11U, 7V), Phyllosticta sorghina 8H (8U); Puccinia recondita, the leaf rust, wheat, 6H (2U, 2V, 2P); Rhizoctonia solani (including R. cerealis) brown patch fungus of turf, 6H (1U, 2V, 3P); Curvularia lunata, leaf spot, 5H (SU); Phyllachora punctum, tar spot, panicgrasses, 4H (2U, 1V, 1P); Phomatospora dinemasporium, 4H (4U); Bipolaris cynodontis, leaf blotch (of Bermuda grass), 3H (2U, 1P); Puccinia coronata, crown rust fungus, 3H (2V, 1P); Stagonospora maculata, purple leaf spot, 3H (2U, 1P); S. arenaria, leaf blotch, 2H (1U, 1V); Cercosporidium graminis, leaf streak, 2H (1U, 1P); Puccinia graminis, black stem rust fungus, 2H (1U, 1V). This is only a partial list of fungi commonly occurring in Virginia whose host range has been extended. A complete summary will be published.

GRAMINICOLOUS FUNGI NEW TO VIRGINIA, 1989-1990. Martha K. Roane and Curtis W. Roane. Dept. Plant Pathology, Physiology and Weed Science, VPI & SU, Blacksburg, Va, 24060. In 1989-90 several fungi on grasses not previously reported in VA were collected. New to the US and VA on new hosts are Bipolaris leersiae, Chaetoseptoria sp., Colletotrichum caudatum, Drechslera bromi, Microdochium bolleyi, Phaeoseptoria festucae var. muhlenbergiae, Phaeosphaeria eustoma, P. fuckellii, P. luctuosa, P. nigrans, P. nodorum, Phloeospora graminearum, Phoma-tospora dinemasporium, Phyllachora vulgata, Phyllosticta anthoxella, P. healdii, P. helenae, P. minutispora, Ramularia graminicola, Septoria tandilensis, Spermosporea subulata, Stagonospora foliicola and S. simplicior. New to VA but not to the US are Cercospora setariae, Drechslera dactylidis, Exserohilum monoceras, Mastigosporeum rubricosum, Rhynchosporina tridentis, Rhynchosporium orthosporum, Stagonospora tridentis and Ustilago spermophora. A complete summary will be published.

PRELIMINARY INVESTIGATIONS OF THE LIFE HISTORY OF THE ENDANGERED PLANT SPECIES ARABIS SEROTINA STEELE (BRASSICACEAE).

Garrie D. Rouse, Environmental Dept., Schnabel Engineering and Associates, Richmond, Va. 23220, & Cheryl A. Rouse*, Medical College of Va./Va. Commonwealth Univ., Richmond, Va. 23298. In July of 1988 the US Fish and Wildlife Service determined Arabis serotina to be a federally Endangered Species. As part of the recovery plan, a several year study of the life history of the plant has been initiated. Two hundred and forty three individuals of A. serotina, from six sites covering the range of the species, were tagged for long-term study and monitored over the 1990 field season. Data on growth, mortality, predation, seed output, etc., were collected to better define the life history of the species. The results from the first year of this multi-year study indicate a high rate attrition among rosettes (48%) and significant predation of bolting individuals by caterpillars (Pieris sp.). The existence of a rhizomatous habit among several individuals of A. serotina was documented. Recommendations for future monitoring efforts will be presented.

PHOTOSYNTHETIC RESPONSES TO TEMPERATURE AND CO₂ IN HYBRIDS BETWEEN FLAVERIA SPECIES OF DIFFERING PHOTOSYNTHETIC TYPE. Tatia J Rowland, RO Littlejohn, Dept. of Biol., Liberty Univ., Lynchburg, VA, 24506, MSB Ku' & GE Edwards', Dept. of Bot., WA. St. Univ., Pullman, WA, 99164. Simultaneous measurements of apparent photosynthesis (A) and quantum yield of electrons transported through PSII (Φ_e , determined from Chl a fluorescence) were obtained for intact leaves of F. floridana (C₃-C₄ intermediate), F. brownii (C₄-like), and their reciprocal hybrids. Temperature optima for both A and Φ_e were close to 30C for F. floridana, 40C for F. brownii, and 35C for both hybrids. Comparison of A and PSII activity suggests an increase in the ratio of photorespiration (PR) to A with increasing temperature for all genotypes while O₂ inhibition of A suggests that levels of PR are highest in F. floridana, lowest in F. brownii, and intermediate for the hybrids. The intermediacy of the two hybrids with respect to PR is further substantiated through comparison of their carboxylation efficiencies and their ratios of CO₂ molecules fixed per electron transported through PSII to those of the two parents. While very little photosynthetic differentiation was evident between the reciprocals, indicating limited effect of maternal inheritance, considerable intermediacy and hybrid vigor were noted as seen by the hybrids' ability to maintain rates of A equaling or exceeding those of both parents at their respective optimum temperatures. The results suggest that, in comparison to the C₃-C₄ parent, an increased expression of C₄ characteristics exists in the hybrids which accomplishes reduced PR and increased efficiency of directing energy derived from PSII toward carbon assimilation.

THE EFFECT OF CULTURE AGE ON THE ABILITY OF SINGLE CELLS OF EUGLENA GRACILIS TO SURVIVE PASSAGE. J.M. Rupe and J.R. Palisano, Dept. of Biology, Emory & Henry College, Emory, VA 24327. The unicellular green alga Euglena gracilis has a finite lifespan in vitro. This lifespan is characterized by a standard growth curve. Preliminary results will be presented which suggest that the stationary and exponential death phase of the growth curve occur independent of the depletion of nutrients and/or buildup of toxic wastes since conditioned medium is capable of supporting the growth of newly inoculated cells. When single cells from cultures of various ages were isolated on solid media and then transferred individually to various volumes of liquid media, the ability of the single cells to survive and multiply is inversely related to the age of the culture from which the cells are obtained. This loss of proliferative potential is independent of the volume of liquid medium in which the single cells are placed. Single cells isolated from 3- to 7-day-old cultures showed no reduction in their ability to multiply; however, cells from 1- and 2-month-old cultures showed a significant decrease in mitotic activity.

VEGETATION ANALYSIS OF FIVE APPALACHIAN BOGS. C. Neal Stewart, Jr., Dept. of Biol. VPI & SU, Blacksburg, Va. 24061. Five northern-type, *Sphagnum*-dominated, treeless, Appalachian bogs (elevation ~ 1000 m) were quantitatively analyzed to compare vegetation using the point-quarter method. The four West Virginia (Pocahontas County) bogs were similar to each other and different than the bog surveyed in Tennessee (Johnson County). The cranberry, *Vaccinium oxycoccos*, was found to be most important in the vegetation structure in W.V., whereas *Rubus hispidus* was determined to be most important in Tenn., followed by *Vaccinium macrocarpon*. In all the bogs surveyed, trailing growth habits are dominant in the vegetation structure. Important graminoid species in W.V. were *Rhynchospora alba* and *Eriophorum virginicum*. These two species were absent in Tenn. where the graminoid growth form was comprised of several codominant sedges and grasses. Edaphic factors, such as pH, and climate, as well as historical factors probably determine the vegetation types found. Bog size was not a factor in species composition diversity, or growth habit of vegetation. Comparisons were also made among other non-Appalachian northern peat bogs.

TEMPERATURE GROWTH RANGES ON POTATO-DEXTROSE AGAR OF REGIONAL ISOLATES OF THE DOGWOOD ANTHRACNOSE FUNGUS, Discula sp. R. J. Stipes and J. L. Ratliff, Dept. Plant Pathol., Physiol. & Weed Sci., Va. Tech, Blacksburg 24061. Since temperature, among other factors, seems to profoundly affect development of dogwood anthracnose (DA) caused by the Ascomycetous fungal pathogen, Discula, we monitored vegetative (linear) growth patterns of 8 isolates from GA, MD, NY, OR, VA & TN on Difco potato-dextrose agar at 7 temperatures (5, 10, 15, 20, 25, 28 & 32C). We herein present data recorded at the 7-day observation period following inoculation. All but 1 isolate (TN) grew some at 5C, and the maximum growth temperature was in the 20-25C range. No growth of any isolate occurred at 28 or 32C. The Oregon isolate from Cornus nuttallii behaved very comparably to all other eastern U.S.A. isolates from Cornus florida. The Discula growth pattern as shown in this study would tend to skew the "preference" of this fungus toward the lower end of the mesophile range. Even though one cannot confidently extrapolate these results to the field situation of disease development, sporulation parameters and pathogen survival, these data on vegetative growth strongly suggest that the disease (DA) may be more severe at the lower end of this temperature-growth testing range.

PROTEIN PROFILES ON ACRYLAMIDE GELS OF REGIONAL ISOLATES OF THE DOGWOOD ANTHRACNOSE FUNGUS, Discula sp. R. Jay Stipes, Jean L. Ratliff and Alice W. Way, Dept. Plant Pathol., Physiol. & Weed Sci., Va Tech, Blacksburg 24061. Only fragmentary data are now extant on certain taxonomic/morphologic aspects of the dogwood anthracnose Discula sp., now decimating dogwood (Cornus florida) populations in the Appalachians. Chemical fingerprinting provides a novel insight into the relatedness of different isolates/strains. We examined 4 regional isolates (DA4 from the Blue Ridge Parkway, Floyd, VA; DA5 from NY; DA6 from GA; and DA7=VA17B from VA). Cultures were grown on liquid potato-dextrose broth for 37 days at 25 C, at which time the mycelia were lyophilized. Protein extracts of mycelia were subjected to SDS-polyacrylamide gel electrophoresis. Coomassie Blue was used as the general stain for proteins sieved through a 12% gel via their molecular wts. About 20-25 bands were noted, mostly in the 26-66 KiloDalton range. Most isolates were remarkably similar, particularly DA4, DA5 & DA6, indicating genetic relatedness. This similarity also might indicate a single virulent pathovar population raging through the dogwood communities. A much more extensive sampling of proteins from diverse strains is now in progress which will provide a more comprehensive perspective of variation in the pathogen.

A NEW RACE OF *Bipolaris zeicola* FROM VIRGINIA. E. J. Traut and H. L. Warren. Dept. of Plant Pathology, Physiology and Weed Science. Virginia Polytechnic Institute and State University, Blacksburg, VA 24061.

Three races and a new pathotype (NP) of *Bipolaris zeicola* (= *Cochliobolus carbonum*) with differential pathogenicity on corn inbred lines have been described. During the summer of 1990, some corn plants in Whitethorne, VA showed foliar symptoms similar to those described for the new pathotype. The pathogen was morphologically similar to isolates of *B. zeicola* races or the pathotype. Fourteen corn inbred lines were evaluated for reaction to races 1, 2 and 3, the NP and the isolate from Whitethorne (WT) under greenhouse conditions. Seedlings were inoculated at the V4-V5 growth stage with a concentration of 10,000 conidia per ml. Lesion type and severity were assessed 2, 5, 7 and 12 days after inoculation. Disease severity was visually estimated on a 1-5 scale. Comparison of the reaction of this set of inbreds to the inoculated isolates shows that the WT isolate has a different genotype from the other three races and the pathotype from the Midwest. Five inbreds showed resistance to the WT isolate. Lesions incited by the WT isolate are oval, tan, and on some inbreds have concentric rings. Lesions of the WT and the new pathotype from the Midwest developed slowly compared to races 1, 2 and 3. However, both the WT and the new pathotype differ in pathogenicity.

AN ACER BARBATUM-RICH FOREST IN THE VIRGINIA COASTAL PLAIN. Donna M. E. Ware and Stewart Ware, Dept. of Biol., Col. of Wm. and Mary, Williamsburg, VA. Acer barbatum Michx. has been regarded as a potential co-dominant of Coastal Plain upland hardwood forests, but has not been found in such forests in recent studies in VA. It seems not to occur on Coastal Plain uplands, but in steep-slope ravines cut through to the calcareous Yorktown Formation underlying the area. Quantitative data from such ravine slope forests in Grove Creek watershed (James City Co.) showed that Fagus grandifolia and A. barbatum were overstory dominants, with Tilia americana a minor associate, and Cornus florida the understory dominant. Several species encountered in the Grove Creek ravines were at or near their northern range limit (e. g., A. barbatum, Bumelia lycioides, Viburnum rufidulum, Ponthieva racemosa, Verbesina virginica) or disjunct from further west (e. g., Quercus muehlenbergii, Magnolia tripetala, Cornus alternifolia, Stewartia ovata, Athyrium pycnocarpon, A. thelypteroides, and the Coastal Plain record Mitella diphylla).

GEL ELECTROPHORESIS PROFILES OF *Colletotrichum graminicola* ASSOCIATED WITH GRASS SPECIES. H. L. Warren, A. W. Way and C. T. Roane. Dept. of Plant Pathology, Physiology, and Weed Science. Virginia Polytechnic Institute and State University, Blacksburg, VA 24061.

Two gel electrophoresis methods were used to characterize isolates of *Colletotrichum graminicola* obtained from cultivated and grass species. Sodium dodecyl sulfate gel (stained with coomassie blue) patterns of soluble protein indicate that isolates of *C. graminicola* from corn, sorghum and grasses can be differentiated based on their host specificity. Isozymes, as performed with polyacrylamide further separated grass isolates into several distinct groups. Corn isolates showed less variability than all other isolates, while sorghum isolates were more variable, which is consistent with results from pathogenicity tests. Isozyme analysis, as performed with polyacrylamide gels can be a valuable tool in the study of genetic variation among fungal organisms.

VIRGINIA'S NATIVE BROME GRASSES, BROMUS SUBGENUS FESTUCARIA. Thomas F. Wieboldt, Massey Herbarium, Dept. of Biology, Va. Polytechnic Inst. and State Univ., Blacksburg, Va. 24061. Four species of native woodland brome grasses are recognized: Bromus ciliatus, B. kalmii, B. latiglumis, and B. pubescens. The confusing nomenclatural history of these taxa is reviewed. Attention is focused on the morphological distinctions between Bromus latiglumis and B. pubescens. Bromus latiglumis may be distinguished by its much larger size, numerous leaves with overlapping sheaths, its velvety leaf sheaths, and the presence of auricles on the collar. Its distribution is shown to be montane and associated with alluvial riparian habitats. A fifth taxon, Bromus nottowayanus, described by M.L. Fernald from the bottomlands of the Nottoway River is considered in some detail. The characters normally used to distinguish the species (number of veins in the glumes) is shown to be unreliable but other characters await further evaluation. Additionally, B. nottowayanus displays certain characters intermediate between B. pubescens and B. latiglumis but quantitative analysis shows discreet morphologies. The taxonomic status of Bromus nottowayanus, nevertheless, remains unresolved for the present.

PHYTOPLANKTON ASSEMBLAGES ASSOCIATED WITH A BLOOM OF *PTYCHODISCUS BREVIS* OFF THE NORTH CAROLINA COAST. Traycie L. West and H.G. Marshall, Dept. Biological Sciences, Old Dominion University, Norfolk, Va. 23529-0266. Between October 1987 and February 1988 a major red tide event occurred off the North Carolina coast causing significant financial losses to the local economy. This extended bloom was caused by the dinoflagellate Ptychodiscus brevis. The relationships during this bloom between other phytoplankton components and this species are being evaluated. Preliminary results indicate other dinoflagellates, diatoms (centrales and pennales species), and chlorophytes also had increased levels of abundance during the bloom period, whereas, cyanobacteria and cells within the picoplankton component have lower concentrations during this period. Other common dinoflagellates during the bloom included Ceratium spp., Prorocentrum spp. and Protoperdinium spp. The diatoms were dominated by neritic species. Cryptomonad populations showed no significant difference before or during the bloom period.

SMALL MAMMALS, HABITAT, AND THE FATE OF FALLEN FRUIT OF AN EXOTIC BUSH HONEYSUCKLE, LONICERA MAACKII. Charles E. Williams, The Nature Conservancy, 1110 Rose Hill Dr., Charlottesville, VA 22901, & Jonathan L. Ralley*, Sch. of Interdisciplinary Studies, Miami Univ., Oxford, OH 45056. Lonicera maackii (Rupr.) Maxim., the Amur or Mongolian honeysuckle, is an exotic invasive shrub that produces a superabundance of low quality, persistent, avian-dispersed fruits. We experimentally examined the role of small mammals as predators of L. maackii fruits in field and laboratory studies to determine: 1) if fruits are chemically defended against predation by small mammals; and 2) the extent of postdispersal fruit predation by small mammals in relation to habitat. Captive deer mice, Peromyscus maniculatus, readily fed on fruits and seeds of L. maackii thus the "persistent fruit defense hypothesis" was not supported. Rates of fruit removal/predation by small mammals (primarily P. maniculatus and P. leucopus) in the field did not differ significantly among forest interior, forest edge or wooded corridor habitats. Overall daily survival rates of fruits ranged from 84.1% to 89.8%

THE CURRENT STATUS AND DISTRIBUTION OF THE HOARY SCULLCAP, SCUTELLARIA INCANA BIEHLER IN VIRGINIA. Robert A. S. Wright, Central Virginia Biological Research Consortium, 5204 Riverside Drive, Richmond, Virginia 23225.

In 1921, Professor Jerome Grimes of William & Mary discovered Scutellaria incana at Matoaca Park in James City County. This plant was later collected there in 1939, 1968 and 1989. Grimes discovered another James City station on the headwaters of Mill Creek in 1921, and it appears to have been rediscovered by Dr. Donna Ware at William & Mary in 1990. In 1936 and again in 1938, John B. Lewis found the plant in two Amelia County locations. A collection made by Barbara and Alton Harvill in Prince Edward County in 1967 has also eluded rediscovery. The author found it in Powhatan County in 1986. To date, only three populations are extant in Virginia, and two are threatened by construction plans. The other population may be threatened in the near future by highway or subdivision development. This presentation highlights the current status, the known stations, threats to known populations, distribution and interesting taxonomy of a truly rare Virginia plant, Scutellaria incana Biehler, the hoary scullcap.

Chemistry

COORDINATED BF_4^- IN COPPER COMPLEXES: PACKING FORCES OR PERMANENT COORDINATION? Mahdi M. Abu-Omar* and W. W. Porterfield*, Dept. of Chemistry, Hampden-Sydney Col., Hampden-Sydney, VA 23943. The BF_4^- ion is in most instances a very poor ligand for transition metals, serving usually as an innocent counterion for cationic species. However, in 1988 two model compounds for copper blue proteins were reported having the copper atom ligated by two imidazole N atoms, two linking thioether S atoms, and a Cl^- counterion, but also by a BF_4^- counterion F atom (6-coordinate). Because a comparable ligand with remote CH_3 groups of no steric significance gave a 5-coordinate geometry without coordinating BF_4^- , it was suggested that packing forces within the crystal had forced BF_4^- coordination. However, we have established through ^{19}F NMR studies that the BF_4^- group remains coordinated in solution, indicating permanent coordination. To the extent that the compounds are true models for copper blue proteins, this indicates an interesting possibility that these proteins can coordinate extremely hard bases from their environment. Arguments are presented for electronic influences within the chelating ligand that might lead to the observed difference between the two compounds.

INFRARED SPECTRAL ANALYSIS: A NEURAL NETWORK APPLICATION IN UNDERGRADUATE INSTRUCTION. Nils W. Ahlgren and Frank A. Palocsay, Dept. of Chemistry, James Madison University, Harrisonburg, VA 22807. Recently, the release of inexpensive neural networking development systems have simplified the examination and prototyping of neural network applications in chemistry. Because neural nets have been particularly effective in applications involving pattern recognition, an infrared spectral analysis network was developed and evaluated. The results show that the chosen neural network shell system can be used to develop a network which effectively identifies infrared spectra. This network could serve as an educational tool in undergraduate instruction.

ROLE OF GYPSY MOTH DEFOLIATION IN THE ACIDIFICATION OF HEADWATER STREAMS. James D. Armstrong Jr., Daniel M. Downey, Dept. of Chem., James Madison University, Harrisonburg, Va. 22807. It is thought that there is a relation between Gypsy Moth defoliation and stream acidification. In the past it has been shown that regions which were clearcut showed stream acidification trends. Cedar Creek near Strasburg, Virginia, showed the same effects after the watershed had been infested by Gypsy Moths.

In order to conduct a thorough study of the impacts of Gypsy Moth defoliation, five streams which form the headwaters of Dry River were chosen. Selection criteria for the streams were based on the similarities in water chemistry, topographical relation to one another, acid sensitivity and the proposed Gypsy Moth impact on the region. Forest Pest Management personnel assessed the area in the summer of 1990 and found 55% defoliation from Gypsy Moths. Defoliation in spring and summer of 1991 is expected to be severe. The situation on these streams will be monitored through the next year in order to assess the affects of defoliation.

COMPUTER SIMULATION OF A LIPID BILAYER AS A SOLVENT. Amy E. Aussiker and Steven G. Desjardins, Dept. of Chem., Washington and Lee Univ., Lexington, VA 24450. A molecular dynamics simulation of a 2 x 16 decanoate bilayer with dissolved spherical solutes is performed to gauge the effect of solutes on bilayer structure. To simplify the simulation, the bilayer molecules are represented as freely jointed chains and the head groups are harmonically constrained in a planar arrangement under an applied force equivalent to 1 atm of pressure. The well known tilt of the lipid molecules within each monolayer is observed, and simulations with 2,4,8,12 and 16 solute particles indicate the extent of bilayer swelling, measured as the average distance between head group planes.

STRUCTURAL ASPECTS OF CHROMATE AND DICHROMATE COMPLEXES OF LANTHANIDE MACROCYCLES. F. Benetollo, G. Bombieri, P. Gilli, P. M. Harlow, A. Polo, L. M. Vallarino, Dept. of Chem., VA Commonwealth Univ., Richmond, VA 23284.

The CrO_4^{2-} ion may be expected to function as an anionic ligand in a $[\text{MX}_n]^{n+}$ complex only when the $\{\text{MX}_n\}$ moiety is either extremely stable or substitution-inert. The latter prerequisite is satisfied by the lanthanide(III) complexes $[\text{M}(\text{CH}_3\text{COO})_2\text{Cl}\cdot n\text{H}_2\text{O}]$, where M is La(III)-Lu(III), L is the six-nitrogen-donor ligand $\text{C}_{22}\text{H}_{26}\text{N}_6$, and n is 3-6. Reaction with potassium chromate in aqueous solution resulted in complete anion metathesis for all members of the series, but the stoichiometry and structure of the products depended on the size of the metal center. The larger lanthanides, La(III) to Nd(III), gave $\text{ML}(\text{CrO}_4)_{1.5}\cdot n\text{H}_2\text{O}$, containing only ionic chromate; the intermediate lanthanides, Sm(III) to Tb(III), gave the yellow $\text{ML}(\text{CrO}_4)_{1.5}\cdot n\text{H}_2\text{O}$, containing both ionic and coordinated chromate, and the brown $[\text{M}(\text{CrO}_4)(\text{H}_2\text{O})\text{L}]_2(\text{Cr}_2\text{O}_7)\cdot 2\text{H}_2\text{O}$, the X-ray crystallographic analysis of which showed the presence of bidentate chelating chromate and ionic dichromate. Finally, the smaller lanthanides, Dy(III) to Lu(III), gave products containing both ionic and coordinated chromate.

THE SYNTHESIS AND CHARACTERIZATION OF IRON-MODIFIED POLYIMIDE FILMS. Joseph J. Bergmeister and Larry T. Taylor, Department of Chemistry, Virginia Tech, Blacksburg, VA 24061-0212. We have found that polyimide films containing an iron oxide microstructure can be prepared by casting and curing a homogeneous solution of a pre-polyimide and an iron complex. The formation of unique features in the films, such as surface layers and bulk particles were dependent upon the iron dopant used. Surface layers of iron oxide (up to 1500 Å) were formed when iron(III) chloride, **1**, was used as the dopant; however, submicron bulk particles of iron oxide were formed when iron (III) acetylacetonate, **2**, was used as the dopant. The synthesis and characterization of various polyimides modified with **1** and **2** will be discussed.

Determination of the Absolute Rate Constant for Chlorine Atom Abstraction from N-Chloroimides by Alkyl Radicals, J. Blackert, J. M. Tanko, Department of Chemistry, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061-0212.

The absolute rate constant for chlorine atom transfer from N-chloroimides to alkyl radicals was measured utilizing the cyclopropylcarbinyl "clock" reaction. The rate constant ($2.5 \times 10^7 \text{ M}^{-1}\text{s}^{-1}$ at 17 °C) is ca. 1000 x smaller than observed for the analogous bromine atom transfer from N-bromoimides. These results are discussed in the context of the potential utility of N-bromoimides in organic synthesis.

POLARIZED LUMINESCENCE AND ABSORPTION SPECTRA OF Tb^{3+} AND Eu^{3+} IN TRIGONAL $\text{Na}_3[\text{Ln}(2,6\text{-pyridinedicarboxylate})_3]\cdot\text{NaClO}_4\cdot 10\text{H}_2\text{O}$. James P. Bolender, David H. Metcalf, and F.S. Richardson, Chemistry Department, University of Virginia, Charlottesville, Virginia, 22901.

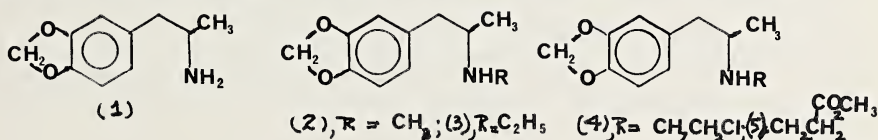
We have measured and analyzed the polarized orthoaxial luminescence and absorption spectra of Tb^{3+} and Eu^{3+} in single crystals of trigonal $\text{Na}_3[\text{Ln}(\text{dpa})_3]\cdot\text{NaClO}_4\cdot 10\text{H}_2\text{O}$ ($\text{dpa} = 2,6\text{-pyridinedicarboxylate} = \text{the dianion of dipicolinic acid}$). Differential linear polarization (σ versus π) is measured in the orthoaxial luminescence and absorption spectra. A semiempirically derived energy level scheme is developed for the crystal field components of the Tb^{3+} ($^7\text{F}_J$ ($J=0-6$), $^5\text{D}_4$, $^5\text{D}_3$, $^5\text{G}_6$, $^5\text{L}_{10}$, $^5\text{D}_2$, $^5\text{G}_5$) and the Eu^{3+} ($^7\text{F}_J$ ($J=0-6$), $^5\text{D}_J$ ($J=0-3$)) multiplets. (This work was supported by a grant from the U.S. National Science Foundation.)

THE DECOMPOSITION OF NICKEL NITRATE HEXAHYDRATE. Lori R. Brock, T. C. DeVore, Dept. of Chem., James Madison University, Harrisonburg, VA 22807. The thermal decomposition of nickel nitrate hexahydrate has been studied using rapid scan infrared spectroscopy. The evolved gases were monitored as a function of time to establish the decomposition rates and degradation mechanisms for the compound. Thermogravimetric analysis was also done to support the mechanisms postulated. The effects of sample size, crystal size, heating rate, and the addition of a carrier gas on the degradation of the nickel nitrate hexahydrate were also studied. Powdered $\text{Ni}(\text{NO}_3)_2\cdot 6\text{H}_2\text{O}$ was observed to decompose in four steps in flowing argon. In the first two steps, which occurred between 315 and 413 K, the hexahydrate water was lost forming the dihydrate. The third step largely involved the loss of the remaining two moles of water, to give the anhydrous nickel nitrate, and was completed by 498 K. The last observed transition lead to the formation of nickel oxide via the evolution of NO_2 .

HEME PROTEIN ELECTRON TRANSFER REACTIONS. Edward Chen and Fred M. Hawkridge, Dept. of Chemistry, Va. Commonwealth University, Richmond, VA 23284. The direct electron transfer reactions of the heme protein, horse heart cytochrome *c*, has now been shown to occur at quasi-reversible rates at several pristine metal electrode surfaces. In this study the electron transfer reactions of cytochrome *c* has been examined at mercury electrodes. The aim of this study has been to delineate adsorption processes that have been widely reported for this highly hydrophobic metal/aqueous interface and the highly hydrophilic surface of this redox protein. The integrity of proteins solutions is believed to have had a central role in much of this work. Using a static mercury drop electrode the differential pulse polarographic responses have been determined as a function of drop life and cytochrome *c* concentration. The thermodynamic, kinetic and adsorption features of these reactions will be discussed.

SURFACE CHARACTERIZATION OF PLASMA-MODIFIED LaRC-TPI. J. W. Chin and J. P. Wightman, Chemistry Department, Center for Adhesive and Sealant Science, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061. Surface modification with radio frequency(RF)-generated plasmas has been widely used in increase wettability and adhesion of polymer surfaces. The goal of this work is to utilize X-ray photoelectron spectroscopy (XPS), infrared reflection absorption spectroscopy (IR-RAS), contact angle analysis and ellipsometry to study the changes induced in the surface of LaRC-TPI, a thermoplastic polyimide, by oxygen, ammonia and argon plasmas. Upon exposure to plasma, significant changes in surface chemistry were seen to develop. All three plasmas caused an increase in the concentration of surface polar groups; contact angle analysis showed dramatic changes in surface wettability. Studies of the rate of polymer ablation indicated that surface chain scission was also occurring.

THE SYNTHESIS AND CHARACTERIZATION OF SOME NEW CENTRAL NERVOUS SYSTEM STIMULANTS. John Chubb and Roy L. Williams, Dept. of Chemistry/Biochemistry, Old Dominion University, Norfolk, VA 23529. This paper will describe the synthesis and characterization of several novel analogues of the 3,4-methylenedioxymethamphetamine parent molecule (1). Some other analogues (2,3) of the parent molecule have previously been shown to have considerable CNS stimulant properties. This research has sought to extend the potential reactivity of the parent system to more functional derivatives such as (4,5), which have been shown to exhibit some interesting CNS activity. The structure activity relationship of these new compounds to the parent systems will be discussed.



PHENOLIC NATURAL PRODUCTS FROM *SPONDIAS MOMBIN*. Kenneth E. Davis and Albert T. Sneden, Department of Chemistry, Virginia Commonwealth University, Richmond, Virginia 23284-2006 and Franklyn Avala Flores, Universidad Nacional de la Amazonia Peruana, Iquitos, Peru.

Spondias mombin (yellow mombin) is a member of the Anacardiaceae family of plants native to tropical parts of the Americas. In Peru, this plant, known as "ubos," is used by native Indians as an antiinflammatory and antidiarrhetic. Various *Spondias* species have been noted in the literature to contain pharmacologically active compounds. As part of our program to identify new, biologically active compounds from plants, an ethanolic extract of *S. mombin* has been investigated. The original extract demonstrated activity in the brine shrimp lethality assay, but subsequent fractions did not confirm this activity. However, the presence of phenolic constituents was detected by spraying the TLC plate of the extract and subsequent fractions with a ferric chloride solution. Several of these phenolic constituents have now been isolated using chromatographic techniques. The isolation and progress in determining the structures of the phenolic constituents will be discussed.

(Supported by a grant from the Jeffress Trust.)

THE SURFACE CHEMISTRY OF COMPOSITES. John G. Dillard, Jack C. Wells, and Bawzana Thompson, Department of Chemistry, Center for Adhesive and Sealant Science, Virginia Tech, Blacksburg, VA 24061-0212. The surface chemistry of adhesively bonded composite materials has been studied. Composite surfaces for non-treated and treated specimens were characterized as to topographical features using SEM and with regard to chemical functionality using XPS. The composite specimens were adhesively bonded after surface treatments including; no treatment, abrasion, application of a primer, and abrasion and application of a primer. The test specimen was a wedge sample. Crack growth in the specimens was followed as a function of time while the specimens were in contact with vapor from concentrated ammonium hydroxide, water, and methanol. The initial failure mode for primed samples was near surface delamination of the composite. Upon exposure of the primed specimens to methanol vapor, the failure mode occurred at the composite/primer interface. The results demonstrate that a weak interaction occurs at the composite-primer interface and that the interaction is degraded by reaction with methanol. Abraded, and abraded and primed specimens upon exposure to methanol failed by severe delamination of the composite. The mode of failure and the rate of failure depended on the surface treatment conditions and the chemical nature of the vapor to which the specimens were exposed.

NEW GADOLINIUM(III) RELAXATION RATE ENHANCERS FOR WATER PROTONS. Kathleen Kahler Fonda and Lidia M. Vallarino, Department of Chemistry, Virginia Commonwealth University, Richmond, VA 23284-2006.

Paramagnetic species lower the T_1 relaxation time of nuclei which interact with the paramagnetic material by providing a more effective pathway for spin-lattice (T_1) relaxation. This phenomenon has been exploited to produce enhanced images in magnetic resonance imaging. We report the results of T_1 measurements of water protons in the presence of $GdLX_3 \cdot nH_2O$, where L is the six-nitrogen macrocyclic ligand $C_{22}H_{26}N_6$ and X is acetate, chloride, or bromide. The complexes $GdLX_3 \cdot nH_2O$ contain a highly inert metal-macrocyclic core which is not decomposed even in acidic or basic media. In the diacetate chloride complex, the acetate ions remain at least partly coordinated in solution, impeding the access of the water molecules to the metal and lowering the efficiency of the complex as a relaxation enhancer. In the trihalide complexes, which contain uncoordinated counterions, the quasi-planar structure of the metal-macrocyclic moiety allows excellent access to the metal center and improved efficiency of the complex as a relaxation rate enhancer.

THERMAL DECOMPOSITION OF $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$

Chip Gaskins*, Lori Brock, T.C. DeVore, Dept. of Chem., James Madison University, Harrisonburg, Va. 22807

The thermal decomposition of trihydrated copper nitrate has been investigated using EGA-FTIR. It is a complex process proceeding through at least four intermediates before forming copper oxide. Nitric acid begins evolving at approximately 365 K. The absorbance of HNO_3 varies as a function of time. HNO_3 evolution increases as transition states are formed and starts to decrease as intermediates begin to form. Evolution of HNO_3 reaches a minimum when a stable intermediate is formed. An unknown copper species sublimates throughout the process. Water evolves at various points during the experiment, but is difficult to measure. Nitrogen dioxide begins to evolve at 470 K and increases as HNO_3 disappears until only copper oxide is formed.

CALCULATION OF VIBRATIONAL FREQUENCY OF CHLOROPHYLL a FROM ITS INTERMOLECULAR DISTANCE IN SOLUTION, FILM, AND CRYSTALLINE STATES

Colmano Germille, Dept. of Biomedical Sciences, VMRCVM, VPI & SU, Blacksburg VA, 24061-0442. The red absorbance peak of the chlorophyll a chromophore (color carrier) shifts its wavelength (frequency of vibration) position, from 665nm to 675nm and 745nm, depending on the intermolecular distance of its molecular packing in solution, film, and crystalline states. Using the molecular orientation of these states, and knowing the intermolecular packing distance in the three different states a model of the shift (coupled with quantum chemistry techniques), may be calculated and constructed. The knowledge of the physical parameters of chlorophyll a in different spatial orientation may explain the correlation of peak position of the red absorption for molecules in solution, film, and crystalline states. The assumption is that the intermolecular distance is inversely proportional to the molecular radius cubed.

EPR AND DNP STUDIES OF SILICA PHASE IMMOBILIZED NITROXIDE (SPIN) SAMPLES.

R.K. Gitti and H.C. Dorn, Chemistry Department, Virginia Tech, Blacksburg, VA 24061

DNP is a general method for increasing NMR sensitivity and studying of weak intermolecular interactions. However the necessity of a low magnetic field (0.035–1.4T) for the effective polarization build up has limited the static approach for studies of simple molecules with a single resonance line.

Recently, a flow transfer DNP method has been developed¹. This approach provides an order of magnitude better NMR detector sensitivity and high chemical shift resolution which made possible measurements of selective DNP enhancements for different nuclei on the same molecule. Particularly attractive is the solid/liquid intermolecular transfer (SLIT) DNP technique which in addition to the above provides better transfer efficiency as well as avoids contamination of valuable samples with paramagnetic species. In the case of SLIT DNP approach the polarization is generated in a low magnetic field (0.33T) utilizing SPIN samples, then transferred (via flow) and detected in a high magnetic field (4.7T).

In this presentation, preparation and EPR characterization of novel SPIN systems suitable for SLIT DNP experiment will be described. Some ^1H and ^{13}C DNP enhancements utilizing the above SPIN samples will be reported as well as SLIT DNP enhancements for enantiomeric pairs in the presence of a chiral environment (e.g. chiral spin labels immobilized on silica gel) will be discussed. (Supported by Jeffres Research Foundation and Petroleum Research Foundation).

1. H.C. Dorn, R.K. Gitti, K.H. Tsai and T.E. Glass, *Chem.Phys.Letters*, 155, 227 (1989).

INTERMOLECULAR CHIRAL RECOGNITION PROBED BY ENANTIOSELECTIVE QUENCHING KINETICS. A MECHANISTIC MODEL FOR DISSYMMETRIC METAL COMPLEXES IN SOLUTION. Deborah P. Glover, F.S. Richardson, and David H. Metcalf, Chemistry Department, University of Virginia, Charlottesville, Virginia, 22901.

We have developed a mechanistic model for enantioselective excited-state quenching kinetics for systems in which quenching occurs via electronic energy-transfer processes within donor-acceptor encounter complexes in solution. This model is applied to systems in which the luminophore (L^*) and quenchers (Q) are dissymmetric metal coordination complexes and in which luminescence quenching rates are slow compared to translational and rotational diffusion rates. The rate parameters derived from enantioselective quenching measurements are expressed in terms of both electronic and stereoselective contributions to intermolecular chiral discrimination, and applications are illustrated for several lanthanide(luminophore)-transition metal(quencher) systems. (This work was supported by a grant from the U.S. National Science Foundation.)

PHYTOCHEMICAL STUDIES OF *HIMATANTHUS SUCUUBA*. Phillip W. Hathcock, Jr. and Albert T. Sneden, Department of Chemistry, Virginia Commonwealth University, Richmond, Virginia 23284-2006 and Franklyn Avala Flores, Universidad Nacional de la Amazonia Peruana, Iquitos, Peru.

Himatanthus sukuuba is a member of the Apocynaceae family of plants which grow as shrubby trees from Panama to the tropical regions of South America. In Peru, *H. sukuuba* ("bellaco caspi") is found in the Amazonian region and is used by native Indians as an anticancer and antirheumatic plant. As part of our program to identify new, biologically active compounds from plants, an ethanolic extract of *H. sukuuba* has been investigated. The original extract demonstrated insecticidal activity against *Drosophila* eggs, but did not show any antibacterial or antifungal activity. The use of the latex from *H. sukuuba* to treat warble fly infections by the Waorani Indians in South America has been documented, and the positive insecticidal activity prompted further investigation of this plant. Trituration of the original extract with dichloromethane resulted in the isolation of a white solid which was composed of several major constituents. Several of these constituents have now been isolated using chromatographic techniques. The isolation and progress in determining the structures of these compounds will be discussed. (Supported by a grant from the Jeffress Trust.)

XPS ANALYSIS OF REDUCED IRON MAGNETICALLY EXTRACTED FROM IRON FORTIFIED BREAKFAST CEREALS. C. L. Heisey, Dept. of Chem., Va. Polytechnic Inst. & State Univ., Blacksburg, Va. 24061, D. Burch, Science Dept., Chatham Hall, Chatham, Va. 24531, & J. P. Wightman, Dept. of Chem., Va. Polytechnic Inst. & State Univ., Blacksburg, Va. 24061. Reduced iron powder was magnetically extracted from commercially available iron fortified breakfast cereals. X-ray photoelectron spectroscopy (XPS) studies determined that the outermost 5 nm of the extracted iron particles contained primarily carbon and oxygen with a small amount of iron and nitrogen. Argon and oxygen plasmas were used to remove the outer layer of organic contamination from the iron powder and increase the percentage of iron in the surface. The binding energy of the Fe2p photopeaks indicated that the outermost layer of the extracted iron powder was oxidized. The range in the size of the iron particles was approximated from scanning electron microscope (SEM) photomicrographs.

PROTEOLYTIC ACTIVITY ASSOCIATED WITH THE WATER STRESS PROTEIN FROM THE CYANOBACTERIUM NOSTOC. Suzanne Hladun and Malcolm Potts*, Dept. of Biochemistry and Nutrition, Va. Tech, Blacksburg, VA 24061. Water stress protein-39 (WSP-39) has been isolated from the cyanobacterium Nostoc which has the unique ability to withstand long periods of desiccation without loss of viability. High levels of WSP-39 are found only in dried colonies with rapid turnover of the protein occurring during the earliest stages of rehydration. Protease inhibitor studies suggest the presence of an extremely active, specific serine protease that is responsible for the observed degradation. Electron microscopy studies localize WSP-39 to the carbohydrate sheath material immediately outside the cell suggesting that WSP-39 is a glycoprotein. Blots stained for both glycoproteins and WSP-39 indicate that observed high molecular weight complexes are a glycosylated form of WSP-39. A possible model for WSP-39's role in protecting the cell during desiccation may be one in which WSP-39 acts as a water barrier to prevent loss of significant amounts of water during periods of drought.

GENOMIC DNA FRACTIONS FROM CYANOBACTERIUM Nostoc commune DIFFER IN BUOYANT DENSITY. Vinita S. Joardar and Malcolm Potts, Dept. of Biochemistry and Nutrition, Va Polytechnic Inst. and State Univ., Blacksburg, VA 24061. The filamentous, heterocystous cyanobacterium Nostoc commune is tolerant to desiccation. Genomic DNA preparations from desiccated and rehydrated colonies of Nostoc commune have been found to contain two distinct fractions of DNA. These two fractions differ in their buoyant density and can be separated by cesium chloride ultracentrifugation. Fraction I DNA has higher buoyant density, is not detectably methylated and is associated with proteoglycan. Fraction II DNA has lower buoyant density, is highly methylated and does not have proteoglycan associated with it. This study investigates the nature of the two DNA fractions.

THE EFFECT OF POLYMER TYPE AND DOSAGE ON COLOR REMOVAL FROM TEXTILE DYE WASTE. Mark C. Joy & David M. Johnson, Life Science Div., Ferrum Col., Ferrum, Va. 24088. Using two types of a cationic polymer, the effects of polymer dosage on color removal from textile dye waste was monitored in three-hour intervals over a four-day period. Color was measured using the A.D.M.I. (American Dye Manufacturing Institute) Method. Effects of percent color removal in samples dosed with three levels of polymer were compared to the untreated sample. The percent color removal was correlated to residual dissolved solids. Also, the absorption spectrum (visible) was recorded for treated and untreated samples to determine the spectral region(s) affected by treatment. Results indicate significant reductions in color can be obtained.

THE ACTIVATION MECHANISM OF MYOSIN LIGHT CHAIN KINASE. Peter J. Kennelly*, Melissa Starovasnik#, James Lorenzen#, Jie Leng*, Petra Marchand*, and Edwin G. Krebs#, *Department of Biochemistry and Nutrition, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061 and #Department of Biochemistry, University of Washington, Seattle, WA 98195. Myosin light chain kinase[MLCK] is a protein kinase whose activity is absolutely dependent upon the binding of the calcium receptor protein calmodulin [CaM] for expression of its catalytic activity. We have proposed that the activity of MLCK is regulated by an autoinhibitory mechanism in which the CaM-binding domain of the protein is in fact bifunctional, with its second function being to act as an myosin light chain substrate binding site-directed inhibitor of enzyme activity when CaM is absent. Three lines of evidence support this assertion. First, synthetic peptides modelled after the CaM binding domain were CaM-controlled inhibitors of enzyme activity. Second, CaM-binding dramatically decreased the thermal stability of MLCK. However, the binding of these model peptides to the enzyme restored stability in a manner analogous to removing CaM. Third, affinity-labelling studies using the nucleotide analog 5'fluorosulfonylbenzoyl adenosine revealed that the MgATP substrate binding site on the enzyme is left essentially unaffected by the association and dissociation of CaM. Thus compound reacted with both MLCK and its CaM complex, and did so with nearly identical kinetic behavior.

THE MILK LIPID SECRETION PROCESS IN MAMMARY EPITHELIAL CELLS. Bridgette H. Keon and T. W. Keenan, Biochemistry Department, Virginia Tech, Blacksburg, VA 24061. A model has been proposed for the mechanism of milk lipid globule (MLG) secretion from mammary epithelial cells (EC) of lactating mammals. Morphological and Biochemical data support an endoplasmic reticular (ER) origin of precursor microlipid droplets (μ LD). A cell-free (CF) system has been developed for the formation and release of μ LD upon incubation of ER in CF mixture. CF μ LD are similar in morphology and lipid composition to in situ μ LD. ER release of μ LD is critically dependent on mammary cytosol (CYT), is time and temperature dependent, and proportional to [CYT]. MLG secretion appears to occur at the apical plasma membrane (PM) of EC. Preliminary data from reducible cross-linking studies suggest an affinity between PM and LD. Addition of dithiothreitol (DTT) reduced LD association with hPM by 42%. CYT prevented LD association to PM. Studies are underway to further define the role of CYT and PM components in the secretion of MLG from EC.

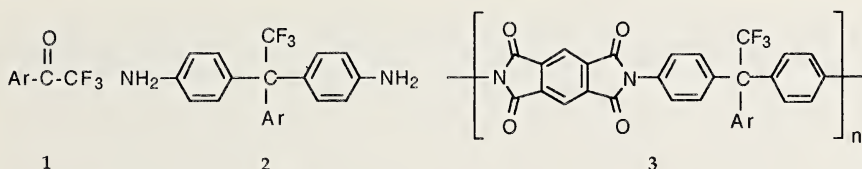
STUDIES ON FLUORESCENT MATERIALS IN HIGHLY ORGANIZED MEDIA. Maria D. Lee*, & Benjamin A. DeGraff*, Department of Chemistry, James Madison University, Harrisonburg, Virginia 22807. Biological membranes are a subject of current and intensive investigation, and emission anisotropy techniques are recent innovations for membrane study. Liquid crystals can provide a suitable model for a number of aspects of membrane organization. I have employed liquid crystals as a membrane model and designed/constructed a system for emission anisotropy studies. This system has been used to measure polarization parameters of luminescent probes in liquid crystal hosts with a goal of modeling biological membrane structure. By applying the technology developed for the liquid crystal system, anisotropy data from actual membrane media will be obtained and interpreted.

THE EFFECTS OF PHOSPHATE ON HUMIC ACIDS ADSORPTION ON VARIOUS SUBSTRATES.

Wing H. Leung & Marie-Rose N. Samba, Dept. of Chemistry, Hampton University, Hampton, Va. 23668. The adsorption of humic acids on various substrates was studied in the presence and absence of phosphate in aqueous solutions. The filtrates were analysed with UV/Vis spectrophotometer for humic acids. The data were analysed using the Langmuir as well as Freundlich equation. The results showed that phosphate inhibit the adsorption on hydrous oxides, while the adsorption of humic acids was increased on activated carbon in the presence of phosphate. The nature of substrates and the pH values of solutions both demonstrated decisive effects on adsorption of humic acids.

NEW MONOMERS AND CONDENSATION POLYIMIDES CONTAINING A PHENYLTRIFLUOROETHYLIDENE LINKAGE. Timothy H. Meeks, Cheryl L. Davis, Lisa M. Reichenbach, and Roy F. Gratz, Dept. of Chemistry and Geology, Mary Washington College, Fredericksburg, VA 22401-5358.

The synthesis of several new aryl trifluoromethyl ketones, 1, and 1,1-bis(4-aminophenyl)-1-aryl-2,2,2-trifluoroethanes, 2, will be discussed. The diamines, 2, will be used to make polyimides, such as 3, containing the phenyltrifluoroethylidene linkage in the polymer chain.



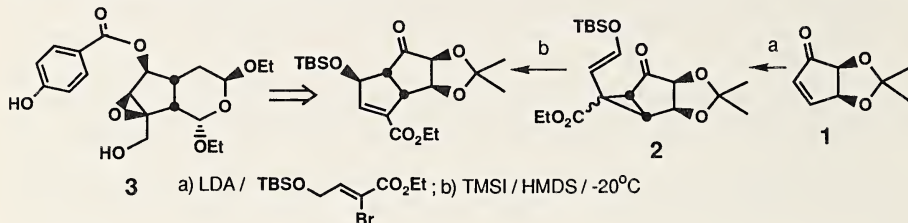
CATALYTICALLY ACTIVE POLYMERS FOR USE IN ELECTRODELESS COPPER PLATING. Manette A. Merritt, Donna S. Amenta, Benjamin A. DeGraff, and John A. Mosbo, Dept. of Chem., James Madison Univ., Harrisonburg, VA 22807. Strongly adhering, high-resolution (e.g., fine-line) copper plating is advantageous in the design of miniature electronic circuits. It was the goal of this project to coat a plastic surface with a thin film (monolayer) of a polymer containing bound catalytic sites that could be activated selectively to promote copper plating. Thus, the preparation of a polymer containing chemically anchored transition metals such as palladium were undertaken. Several approaches were used. The first of these involved chemical transformations directly on a polystyrene backbone. The materials so obtained were not satisfactory for our purposes; consequently, alternative synthetic approaches involving the construction of the metal bound polymers from monomers were sought. The reaction sequences from all of these approaches, as well as the subsequent studies, will be discussed.

A GENERAL SYNTHESIS OF β -ALKYLPYRIDINES AND β -(ω -ALKENYL)PYRIDINES. Matt Milkevitch and Wayne M. Stalick, Department of Chemistry, George Mason University, Fairfax, VA 22030. Alkylpyridines have been identified as major constituents of oil shale and lower rank bituminous and lignite coals. In order to develop a better understanding of the decomposition pathways of these materials, a study of the thermolysis reactions of β -alkylpyridines has been initiated by our research group. During the breakdown of long chain alkylpyridines, a mixture of shorter alkyl- and alkenylpyridines are produced. To better characterize the products and to examine their breakdown parameters, it was necessary to synthesize some of these breakdown products. The synthesis of many alkylpyridines had been achieved using a modified Brown and Murphey synthesis and this procedure is now extended to include the β -alkenylpyridines as well. An interesting observation during this synthesis is that the amount of monoalkenylation vs dialkenylation seems to depend upon the distance of the double bond from the aromatic ring. This effect along with the yields and the characterization of the products of these reactions are presented.

LOW TEMPERATURE REARRANGEMENT OF VINYLCYCLOPROPANES TO CYCLOPENTENES.

APPLICATION TO THE ENANTIOSPECIFIC SYNTHESIS OF (-) - SPECIONIN, Tomas Hudlicky, Michael Natchus, Alison Fleming, Nina Heard, Department of Chemistry, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061.

Nonpyrolytic conditions suitable for the vinylcyclopropane / cyclopentene rearrangement for compounds of type 2 have been investigated and applied in the enantiospecific synthesis of (-) - Specionin 3 from 1. The progress of the total synthesis of 3 will be presented.



HETEROBIMETALLIC DIPHOSPHINE COMPLEXES: SYNTHESIS, CHARACTERIZATION AND REACTIONS. Lori Nixon, Michelle M. Setzer and Serge Schreiner, Dept. of Chem., Randolph-Macon Col., Ashland, VA. 23005. Bimetallic transition metal complexes have great potential for the development of multicentered catalysts since both metal centers are accessible to bind small molecules. In order to determine the potential benefits of cooperative bimetallic activation, the synthesis of homo- and heterobimetallic complexes has been explored. Low-valent complexes of the MM'(μ-dppm)₂ series (M = Pd; M' = Ni, Pd; dppm = bis(diphenylphosphinomethane) have been synthesized and characterized. These complexes have a common molecular framework, but differ in the metal's oxidation state and degree of coordinative saturation. The synthetic procedures leading to these complexes as well as their characterizations will be detailed.

SEARCH FOR MORE EFFICIENT ZERO-VALENT PALLADIUM CATALYSTS THROUGH VARIATION OF THE ELECTRONIC AND STERIC PROPERTIES OF PHOSPHINE LIGANDS. Godson C. Nwokogu and Daniel Owusu*, Department of Chemistry, Hampton University, Hampton, VA 23668.

The rate determining step in useful palladium(0)-catalyzed C-C bond forming reactions is the oxidative addition of the substrate to a Palladium(0)-complex. In this step, the Pd-atom is acting as a nucleophile. Increasing the nucleophilicity at Pd in the complex through more electron-rich ligands may, therefore, lead to more efficient catalysts. In order to test this, we have prepared one new and one known tris(trimethoxyphenyl)phosphine and a known tris(dimethoxyphenyl)phosphine. These highly nucleophilic(basic) and bulky phosphines are to be compared with standard ligands such as triphenylphosphine in Pd-catalyzed C-C bond forming reactions.

Our efforts in preparing the triarylphosphines and preliminary results from their evaluation as ligands in Pd(0)-catalyzed reactions will be presented.

THE SYNTHESIS OF 8-AZIDO-S-ADENOSYLMETHIONINE AND ITS USE AS A PHOTOAFFINITY LABEL OF A METHYLTRANSFERASE. Keith A. Oxenrider and Thomas O. Sitz, Dept. of Biochem., Virginia Tech, Blacksburg, VA 24061-0308. The guanine-7-methyltransferase that methylates the "cap" structure in eucaryotic mRNA is very important in gene expression. If the 7-position of the guanine is not methylated in the "cap" structure, processing and translation of the mRNA into protein is dramatically restricted. We have defined three domains in the active site of this methyltransferase, the AdoMet binding region, the "cap" region, and the RNA binding domain. We have synthesized 8-azido-S-adenosylmethionine (8-azido-AdoMet) as a photoaffinity label using S-adenosylmethionine synthetase isolated from rabbit liver. The product, 8-azido-AdoMet, was isolated on a phosphocellulose column with a yield of 22%. The 8-azido-AdoMet had a characteristic UV adsorption spectra and showed rapid photolysis with a germicidal UV lamp. The 8-azido-AdoMet reacted with dithiol reagents used to stabilize the methyltransferase, but did not react as rapidly with mono-thiol reagents. Preliminary experiments showed that this azido compound could inhibit the guanine-7-methyltransferase.

MULTICOMPONENT CALIBRATION AND ANALYSIS IN LIQUID CHROMATOGRAPHY. Russell B. Poe, Todd L. Cecil, Sarah C. Rutan, Dept. of Chem., Va. Commonwealth Univ., Richmond, Va. 23284. Photodiode array detectors have been used to improve the detection capabilities in liquid chromatography. In this work, different methods are investigated to improve the quantitative results obtained from liquid chromatography using full spectrum fluorescence detection. The advantage of multiple wavelength detectors compared to single wavelength detectors is that multiwavelength information can be used to resolve and quantitate overlapping peaks. Different approaches such as multiple linear regression, Kalman filtering, and rank annihilation have been investigated for multicomponent calibration using fluorescence detection in liquid chromatography.

COMPARATIVE ANALYSES OF Nd^{3+} ($4f^3$) ENERGY-LEVEL STRUCTURES IN VARIOUS CRYSTALLINE HOSTS. John R. Quagliano, and F.S. Richardson, Dept. of Chemistry, Univ. of Virginia, Charlottesville, VA., 22901 (USA) and M. F. Reid*, Dept. of Physics, Univ. of Hong Kong, (Hong Kong). We have performed an in-depth analysis of the energy-level structures in seven Nd^{3+} ($4f^3$) crystal systems: $[\text{Nd}(\text{H}_2\text{O})_9] \cdot 3\text{CF}_3\text{SO}_3$, $\text{Nd}^{3+}:\text{Cs}_2\text{NaGdCl}_6$, four Nd^{3+} -doped garnets ($\text{Nd}^{3+}:\text{A}_3\text{B}_5\text{O}_{12}$), and $\text{Nd}^{3+}:\text{CsCdBr}_3$. A model Hamiltonian employing 20 free-ion operators and the appropriate one-electron crystal-field interaction operators was diagonalized within the full 364 SLJM_J basis of the f^3 electronic configuration. Ample spectroscopic experimental data allowed us to use least squares fitting routines to produce a crystal-field energy-level structure for Nd^{3+} in each host. Particular attention is given in this report to trends in the values of the free-ion parameters among the seven hosts. Although similar free-ion values are expected, the atomic (ionic) radius and the charge of the coordinating species can lead to changes in the extent of free-ion interactions. The effects of specific two-body correlation crystal-field operators (originally proposed by Judd and later studied by Reid) will also be discussed. (Work was performed with support from the National Science Foundation.)

MATHEMATICAL AND INTUITIVE INTERPRETATIONS OF THE FOURIER TRANSFORMATION. C. C. Sauer, L. M. Rieck, R. J. Gentile and J. J. Leary: Department of Chemistry, James Madison University, Harrisonburg, VA 22807.

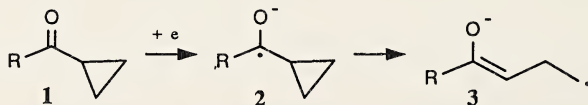
From the chemist's prospective, applications based upon the work of Jean Fourier (1768-1830) remained dormant until 1965, when Cooley and Tukey published one of the first fast Fourier transform algorithms (FFT). The availability of both FFT algorithms and powerful computers has led to the nearly explosive growth of analytical instrumentation that utilizes Fourier data reduction techniques (e.g. FT-IR, FT-NMR, FT-MS, FT-Raman, etc.). This presentation will focus on both intuitive and mathematical aspects of the Fourier transformation. In general, the functions to be transformed will be simple sines, cosines and their composites. Among the topics that will be discussed are: interference, frequency limits, symmetry, periodicity and the effect of displacing the function.

PHOTOCHEMICAL FORMATION OF THE DIPHENYL METHYL RADICAL WITH SUBSEQUENT OXIDATION BY METAL IONS. Morgan S. Sibbald and B. A. DeGraff, James Madison Univ., Harrisonburg, Va. 22807. Steady illumination ultraviolet photolysis of the s-tetraphenyl acetone molecule causes a decarbonylation reaction with the formation of two diphenyl methyl radicals. In the presence of certain metal ions, the radical can be oxidized to form the diphenyl methyl carbocation and a reduced metal, or possibly an organometallic species. The carbocation or organometallic species immediately reacts with the nucleophilic solvent methanol to produce an ether. Data and its interpretation characterizing the ketone's photochemistry, as well as the radical's fate both in the absence and presence of metal ions will be presented.

THE SYNTHESIS OF 4'-ISOCYANO-BENZO-15-CROWN-5. Elizabeth A. Smith, Abbey D. Heath, Donna S. Amenta, John A. Mosbo, Dept. of Chem., James Madison Univ., Harrisonburg, VA 22807. Through a series of synthetic steps the previously unreported title crown ether was prepared. Using literature procedures, nitration of the commercially available benzo-15-crown-5 provided the 4'-nitro crown ether, which was subsequently hydrogenated to yield 4'-amino crown ether. The previously unreported formanilide derivative was then synthesized utilizing acetic formic anhydride. This compound was dehydrated with a phosphine, carbon tetrachloride, and triethylamine to yield the target molecule. Details of the latter two synthetic steps and initial attempts to prepare platinum complexes of the isocyanide ligand will be described.

ELECTRON TRANSFER PROBES: REARRANGEMENTS OF ARYL CYCLOPROPYL KETYL ANIONS. James M. Tanko and Ray E. Drumright, Department of Chemistry, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061-0212.

Cyclopropyl-containing substrates (e.g., 1) have often been employed as diagnostic probes for single electron transfer in organic chemical reactions. The implicit assumption in such studies is that the detection of rearranged (ring-opened) product(s) can be ascribed to the intermediacy of a cyclopropyl ketyl anion radical (2 → 3):



Results will be presented which demonstrate while aryl cyclopropyl ketyl anions do ring open, the process is reversible.

SUBSTITUENT EFFECTS ON THE GEOMETRY OF THE CYCLOOCTATETRAENE RING. Carl Trindle, Chemistry Department, University of Virginia, Charlottesville, VA 22903 and Troy Wolfskill*, Chemistry Department, Lycoming College, Williamsport PA 17701.

Cyclooctatetraene can achieve a variety of geometries: tub, crown, chair, and octagonal or distorted planar forms, depending on the system's charge and spin multiplicity. Our *ab initio* computations, which produce optimum geometries, relative energetics, and vibrational frequencies, provide a coherent story of the influences of charge and spin, consistent with a Walsh analysis.

Since acceptor and donor substituents may alter the net charge on a cyclooctatetraene ring, such substituents might affect the geometry of the ring. We used the AM1 model for the wave function and electronic energy to evaluate the impact of substituents on charge distribution in the ring, and on the inversion barrier. Qualitative perturbation-molecular-orbital analysis suggests that substituents would force charge alternation in the ring, reduce bond-length alternation, and lower the inversion barrier. These predictions were borne out for a model donor ($-\text{CH}_2$ anion) and a model acceptor ($-\text{CH}_2$ cation). However more easily accessible substituents, the donor methoxy and the acceptor formyl, had minor effects on the inversion barrier. Multiple acceptor or donor substitution and push-pull substituents exaggerated the charge alternation, but had little impact on inversion barriers. Fused-ring derivatives, such as the bis-cyclopenta-cyclooctatetraenes, suffered less of the bias arising from sigma-system strain toward a puckered singlet cyclooctatetraene ring, and in these systems electron donors were particularly effective in flattening the ring.

ANALYTICAL APPLICATIONS OF CHITIN/CHITOSAN, I.T. URASA AND JULIO C. ARCE, Department of Chemistry, Hampton University, Hampton, VA. 23668.

Chitin, a polysaccharide, is biomass produced by marine animals, insects, and fungi. Biomass materials are known to accumulate metal ions by the process of biosorption in which chemical functional groups found in the cell wall biopolymers interact with the metal ions. Binding sites include amines, imidazoles, amides, hydroxyls, thiols, phosphates, and carboxylates. In some cases, covalent bonding is involved, making these materials suitable as complexing agents.

Chitosan is a form of chitin in which the acetylated amino groups have been converted into simple amino sites by reaction with hot alkali. This enhances the reactivity of the polymer towards metal ions.

However, very few reports have appeared in the literature showing how these very prevalent biomass materials can be effectively used in environmental problems. Our work has shown that these materials can be tailored towards the immobilization of priority pollutants, such as lead, in natural waters, soils, and sediments.

LIMESTONE TREATMENT OF ACIDIFIED STREAMS. Jeffrey D. Wagman and Dan Downey, James Madison University, Harrisonburg, VA 22807. The goal of this study is to evaluate the mitigation of the acidification of streamwater through single-point application of limestone. Acid rain is primarily formed when nitrogen oxides (NO_x) and sulfur oxides (SO_x) emitted from the burning of fossil fuels react in the atmosphere to form Nitric and Sulfuric acids, respectively. These acids return to earth where they enter streams through rain runoff and underground water displacement. The sulfate ion reduces the stream's buffering capacity by replacing the natural carbonate and bicarbonate. Limestone is calcium carbonate (CaCO_3) which dissolves sufficiently in streams to provide supplemental carbonate ions to boost buffering capacity. The effectiveness of the treatment has been found to be dependent on several parameters including the mass, particle size, and purity of the limestone, the stream gradient, flowrate and existing water quality and the total acid loading in the watershed.

DIRECT PYROLYSIS/FTIR INVESTIGATION OF THE DECOMPOSITION OF POLYMERS

Michael T. Waroblak* and T.C. DeVore, Dept. of Chemistry, James Madison University, Harrisonburg, VA. 22807

Rapid scan Fourier Transform Infrared Spectroscopy is being used in conjunction with vacuum pyrolysis to investigate the dynamics of the thermal decomposition of polyvinyl chloride (PVC), polytetrafluoroethene (PTFE), polystyrene (PS), natural rubber poly(cis-isoprene), and ethene-vinylacetate (ETVA) copolymers. The DTA-FTIR software was used to investigate the initial decomposition of each polymer. PTFE and PS unzip to give their respective monomers (although PS also gives segmers). Natural rubber displays depolymerization and cycization mechanisms. PVC and ETVA give HCl and acetic acid respectively. ETVA copolymers provided valuable information regarding secondary pyrolysis mechanisms.

INFRARED ANALYSIS OF ULTRA THIN POLYMERIC FILMS ON METAL SUBSTRATES. H. F. Webster, and J. P. Wightman, Department of Chemistry, Virginia Tech, Blacksburg, VA 24061-0212. An understanding of the specific chemical and physical forces at work in the interphase region between adhesive and adherend is crucial in the understanding of the bond strength and durability in adhesive systems. Due to the nature of most adhesive systems, however, direct analysis of this interphase region is usually hampered by the geometry of the test system, and chemical analysis restricted to post fracture analysis. Analysis of thin polymeric films (< 100 nm), may provide a means to simulate and probe the interphase region under a variety of environmental conditions. This work focuses on the analysis of thin polymer films on metal substrates using the techniques of Fourier transform reflection-absorption infrared spectroscopy (FT-RAIRS), X-ray photoelectron spectroscopy (XPS) and ellipsometry. [Research supported in part by the Adhesive and Sealant Council, Ford Motor Co. and the Phillips Petroleum Co.]

CARBENE STUDIES OF BICYCLICS. George S. Whitney, Michael Sebesta, and William Brinkman, Department of Chemistry, Washington & Lee Univ., Lexington VA 24450. The toluenesulfonyl hydrazone derivative of the bicyclic ketone Fenchone is difficult to make because of steric hindrance. We have made it and decomposed it with base to extend our studies of carbene-to-tricyclene type molecules.

PHYSICAL STUDY OF CROSSLINKED POLYIMIDES. Carl A. Williams, Dept. of Chem, VPI, Blacksburg, Va. 24060, and T.C. Ward, Dept. of Chem, VPI, Blacksburg, Va. 24060. The importance of this research lies in the fact that adhesives provide economical advantages over conventional fastening techniques. Insight into the physical properties of these adhesives would yield valuable knowledge in determining the possible uses for these materials. The type of adhesives that were studied were lightly crosslinked polyimides that were formed by reacting maleated polypropylene with a couple different types of aliphatic diamines. Thermal analysis and other polymer characterization techniques were performed on the resulting polymers and these tests proved that a crosslinked system did exist. The future research will focus on the mechanical testing of the adhesive bond using various combinations of metal and composite substrates. (Supported by CASS Fellowship VPI)

THE SEARCH FOR PROCYANIDINOLS IN VIRGINIA WINES. Roy L. Williams, Dept. of Chemistry/Biochemistry, Old Dominion University, Norfolk, VA 23529, & Jacques Recht, Ingleside Plantation Vineyards, Oak Grove, VA. A group of polyphenolics known as the procyanidinols have been shown to exist in relatively high concentrations in various components of grapes and in finished wines. These compounds have been the focus of considerable research in Europe and now at Old Dominion University as a result of their unique biological activity. This paper will describe our efforts in the analysis and identification of these unique compounds by HPLC and describe our results of the analysis of a variety of red wines from Virginia with regard to their procyanidinol content.

DETERMINATION OF ORTHO-PHOSPHATE LEVELS IN NATURAL WATER SAMPLES USING AN AUTOMATED ROBOTICS ANALYSIS SYSTEM. Deirdre A. Zarganis, Michael A. Pleva and F. A. Settle*, Dept. of Chemistry, Washington & Lee Univ., Lexington, VA 24450. *Virginia Military Institute. The purpose of this research was to create an automated system that will correctly predict the concentration of orthophosphate in water samples. By automating the analytical method, we hope to increase the reliability of the data by minimizing the involvement of the analyst in the performance of the routine tasks required by the analysis. In the analysis standard reagent grade ammonium molybdate is added to the water sample to convert any orthophosphate to molybdophosphoric acid. Standard reagent grade stannous chloride dissolved in HCl is then added to reduce the colorless molybdophosphoric acid to an intensely colored molybdenum blue. The physical property of color is then related to the concentration of phosphate by a Beer's law calibration curve at a wavelength of 690 nm. The system was proven to obey Beer's law, with a linear fit justified for the data. While the intercepts vary slightly, the slopes do not change. The automated analysis for orthophosphate in water samples by the stannous chloride method thus far can predict the concentration of phosphate with less than ten % error.

METABOLIC C-FORMYLATION OF THE IMINIUM ION METABOLITE DERIVED FROM PHENCYCLIDINE. Zhiyong Zhao, Louis Y. Leung,* Anthony Trevor,* and Neal Castagnoli, Jr., Dept. of Chemistry, Virginia Tech, Blacksburg, VA, 24061 and *Dept. of Pharmacology, University of California, San Francisco, CA 94143. The fate of the 1-(1-phenylcyclohexyl)-2,3,4,5-tetrahydropyridinium species, a principal metabolite derived from the psychosis inducing agent phencyclidine [1-(1-phenylcyclohexyl)piperidine, PCP], has been examined in brain subcellular fractions. A metabolite isolated from these incubation mixtures displayed on HPLC-diode array analysis a chromophore with λ_{max} 302 nm and on probe EIMS analysis an exact mass of 269.3900 corresponding to an empirical formula of $\text{C}_{18}\text{H}_{23}\text{NO}$ which in turn is equivalent to the addition of CO to the substrate molecule. These data prompted us to propose 1-(1-phenylcyclohexyl)-5-formyl-1,2,3,4-tetrahydro-pyridine as a likely structure for the metabolite. The synthesis of this aminoal was achieved by treatment of 1-(1-phenylcyclohexyl)-2,3,4,5-tetrahydropyridine with N-formylimidazole. The GCMS characteristics of the fully characterized synthetic standard were identical to those of the metabolite. These results suggest that enamines may undergo metabolic C-formylation presumably via a transformylation process involving N^3 -formyltetrahydrofolic acid (folinic acid) and/or the corresponding N^{10} -formyltetrahydrofolic acid.

Computer Sciences

A SIMPLE STOCHASTIC MODEL FOR COMPUTER TERMINAL AVAILABILITY.

Robert G. Brookshire & Scott P. Stevens, Dept. of Information & Decision Sciences, and Stinson H. Lenkerd, Academic Computing Services, James Madison Univ., Harrisonburg, VA 22807. Although queueing models have been widely applied in the analysis of computer performance and in the provision of services to individuals by multiple servers, these models have rarely been applied to the provision of computing services to individuals. We develop a queueing model based on the Erlang function for the availability of computer terminals in an academic computing laboratory. This model has the advantages of providing estimates of the numbers of computer users unable to obtain services, and of being comparable to standard performance measures for communications equipment. It also generates measures of resource availability which may be analyzed dynamically. Examples of the use of this model are provided.

GRAPHICS ON A NeXT WORKSTATION. Maria H. Lam, Department of Computer Science, Hampton Univ., Hampton, VA 23668. Four years ago the NeXT Inc. introduced the NeXT workstation. The NeXT environment is different from that of the most microcomputers in that it adopts the object-oriented concepts. The underlying language is Objective-C which is an extension of the C language. It also provides users with powerful software such as the Interface Builder such that elegant application interface can be developed by using little more than a mouse or simple programming. Therefore one can rapidly generate a graphical front-end for his/her application. We use a NeXT workstation to develop a 3D map of the world. By specifying the latitude and longitude of a viewing point, a user can view the world from any point with hidden lines removed. The program is written in object-oriented ForTran. The experience of producing this map will be discussed. This work is supported by Naval Surface Warfare Center under contract N60921-89-R-A149.

BINARY SEARCH IN MULTIPROCESSOR MODELS. Ernest L. Oliver and Dr. Pradip P. Dey, Dept. of Computer Science, Hampton Univ., Hampton, Va. 23668. Since searching is such a common activity in the computing sciences, it is desirable to find an efficient method for performing it. If the space to be searched is ordered and relatively large, the binary search is an ideal search method. The high performance of the binary search can be attributed to the halving of the search space each time a comparison is made. This is accomplished by repeatedly locating the middle element and determining if it is larger or smaller than the element being searched for. To search a list, it takes $\log_2 n$ time, where n is the size of the list. By parallelizing the binary search, several elements in the list can be searched for simultaneously. Ideally, in the parallelized procedure, the shared memory multiprocessor architecture (MIMD) can search for p elements in $\log_2 n$ time, where p is the number of available processors. Investigating and developing efficient algorithms to be implemented in multiprocessor models is the focus of this research.

PREVENTING MICROCOMPUTER VIRUSES IN PUBLIC-ACCESS FACILITIES.

Anthony D. Townsend, Academic Computing Center, University of Virginia, Charlottesville, VA 22903. Coordinators of academic microcomputer facilities have to deal with an increasing threat of both Macintosh and PC viruses. This presentation will examine some of ways to prevent them in public access rooms. This will also include a brief look at the major types of viral infections, offer ways to detect them, and also look at different methods of eradication.

TREE COMPACTION. Lennore L. Vinnie, and Dr. Larry Morell, Dept. of Computer Science, Hampton Univ., Hampton, Va. 23668. Tree structures are fundamental to the study of Computer Science. They are used for structuring data bases and file systems. Information from programs can be stored in the form of a tree. This type of tree is called a parse tree. One reason for storing a program in the form of a parse tree is to provide greater editing capabilities, for example, positioning at the next statement, finding an identifier's declaration, and pretty printing the program. However, a major disadvantage of a parse tree is the enormous amount of space it requires. Therefore, some technique is necessary to compact the parse tree without sacrificing its benefits. Investigating and implementing such methods to compact parse trees is the focus of this research.

Education

THE DESIGN AND EVALUATION OF A PROJECT 2061 MODEL SECONDARY MAGNET SCHOOL. Michael L. Bentley. Southwest Virginia Governor's School, 304 Harvey Street, Radford, Va. 24141. To meet the educational needs of academically talented students and to replenish the country's dwindling pool of scientists and engineers, secondary magnet schools for science and technology have proliferated throughout the country. The more recent schools have been influenced by Science for All Americans (1989), the project 2061 study of the American Association for the Advancement of Science. In 1990, a regional secondary magnet school was created in southwestern Virginia as 1 Project 2061 model to serve eight school districts. The school's program and features, as well as the evaluation plan, will be discussed.

ORGANIC CHEMISTRY FOR DAILY LIFE: A UNIT FOR THE HIGH SCHOOL COURSE. Jennifer C. Bullock and Thomas G. Teates, Virginia Tech, Blacksburg, Va. 24061. In recent years new pharmaceutical and polymer products have been put on the market at an exponential rate. At the same time there has also been a decrease in the number of students interested in scientific careers. We have designed a program to expose students to the basics of organic chemistry using examples from polymer and pharmaceutical products for relevance. The two basic goals of the program are to stimulate interest in chemistry by use of relevant topics and to give students information which will allow them to make informed consumer decisions. Plans are underway for field testing the program and will be discussed in the presentation.

USE OF THE LASER MODEL IN PRESERVICE SCIENCE TEACHER EDUCATION. George E. Glasson and Rosary V. Lalik, Div. of Curriculum & Instruction, Va. Polytechnic Inst. & State Univ., Blacksburg, Va. 24061. The LASER Model is an instructional framework for engaging students in the reciprocal use of language and action in science classrooms. The model has three instructional phases: exploration, clarification and elaboration. Preservice elementary and middle school teachers were engaged in using the model during science methods courses by investigating the topics of reflection and refraction of light. These teachers subsequently planned, taught and videotaped instruction using this model in their field student teaching placements. They examined their own teaching by analyzing the videotaped instruction, designing portfolios and writing about their experiences. Informal analysis of these prospective teachers' work indicated that they developed more confidence in their abilities to be successful science teachers and an increased interest in learning science content. (Supported by the Reading to Learn Program of the Virginia Department of Education).

A VYGOTSKIAN PERSPECTIVE ON THE USE OF DIALOGUE IN THE SCIENCE CLASSROOMS. Rosary V. Lalik and George E. Glasson, Div. of Curriculum & Instruction, Va. Polytechnic Inst. & State Univ., Blacksburg, Va. 24061. The presentation focused on the Vygotskian tradition in psychology and its implications for science education. Vygotskians emphasize the interplay between speech and action in the development of internal psychological functions and the notion of an externalized form of mind, known as the construction zone. In this zone, learners bring their unique cultural histories and, with the assistance of others, combine dialogue and action to accomplish purposeful activity. This theoretical perspective is particularly useful to science educators because it provides a basis for attracting and supporting the participation in science of minority and female populations. (Supported by the Reading to Learn Program of the Virginia Department of Education).

PHILOSOPHY AND BEHAVIOR: CONFLICT IN ACADEME. Bernard H. Levin, Blue Ridge Community College, Weyers Cave, Va. 24486, & Darrel A. Clowes, College of Education, Virginia Tech, Blacksburg, Va. 24061. Complaints about our system of education, including higher education, have nearly overwhelmed existing intra-institutional processes and made them increasingly vulnerable to external political forces. The wide-spread belief that nothing is right in education has resulted in testing for minimum competencies, for pre-post changes, and even for "thinking skills." Throughout our mensuration spasms, operationalized skills are the focus, rather than more global cognitive processes. Higher education continues in a positivist mode of thought while the intellectual world has left this mode, moved into modernism and now is tentatively approaching post-modernism. This cultural lag is an explanation for the frustration we experience with current policy on student educational outcomes assessment.

USING COMPUTERS FOR DATA ACQUISITION AND ANALYSIS IN THE PHYSIOLOGY TEACHING LABORATORY. Mark M. Mast, Kenton K. Brubaker, A. Clair Mellinger, and Roman J. Miller, Dept. of Biol., Eastern Mennonite Col., Harrisonburg, VA 22801. In an attempt to modernize, upgrade, and revitalize physiological laboratory instruction, we have recently installed nine IBM-compatible computer workstations (Hyundai super 386C, 20 mHz, 80387 math coprocessor, VGA color monitor, 40 mb hard disk) interfaced to physiograph recording systems (Minigraph, Lafayette). Lab Tech Notebook (LTNB), our data acquisition program, obtains data through an eight channel analog-to-digital board (DAS-8PGA, MetraByte). LTNB is compatible with our major software package, Microsoft Works, which integrates word processing, spreadsheet, graphics, and database components. As an example of the system's capabilities, we have recently programmed it to analyze a typical frog heart ventricular myogram obtained via a force transducer. Data, received at a rate of 100 Hz by LTNB, are displayed in several ways on the computer monitor in real time fashion as: (1) graphic representations of the ventricle contraction waves, (2) numerical displays of the current contraction rate (beats/min) and (3) quantifications of the areas under the contraction curves (area/min and area/contraction). Display data are simultaneously recorded in a data file on the computer's hard disk. Selected portions of this data file can be easily transferred into Microsoft Works for further analysis and for permanent charting. This system readily allows for visual and quantitative assessments of influential factors, such as temperature or drugs, that alter heart rate or contractile strength. While the overall system is complex and powerful, it is user-friendly enough to allow undergraduates to learn how to operate and even program it. (Research funded by Grant #USE-9051156, National Science Foundation and D.B. Suter Endowment for Biology.)

A CONCEPT WHEEL: A TOOL FOR CURRICULUM AND INSTRUCTIONAL DESIGN John W. McLaughlin, College of Education, Div. of Curriculum and Instr., VA Polytechnic Inst. and State Univ., Blacksburg, VA 24061-0313. Science education and science curriculum have been obsolete for many generations. Recently, reform in curriculum and instruction in science education has emphasized conceptual and hands-on learning, the development of critical thinking skills and an encouraged study of science in our society. Educators who are encouraged to implement these elements in their curriculum and instructional planning, and who have been departmentalized for many years, may find it difficult to make all of the conceptual connections in the curriculum. Expanding on the concept mapping theory by J. Novak, Cornell University, the construction of a conceptual wheel lesson plan allows teachers and students to make visual interconnections between specific curriculum concepts while allowing for the further development of critical thinking skills via creative instruction.

CONCEPT MAPPING: THE HYPERCARD APPROACH Manette Monroe, Virginia Polytechnic Institute & State University, Blacksburg, VA 24060. Concept mapping is a learning tool to help students develop higher-order thinking skills. The recommendations encompassed within Project 2061 are uniquely suited to application of concept-mapping techniques. Relationships and understanding are emphasized over simple memorization of a large number of facts. A program utilizing Hypercard on the Macintosh computer was created as an alternative approach to concept mapping. Animation and graphical representation were employed to help students better understand the conceptual information in a "user-friendly" atmosphere.

THE USE OF HYPERCARD TO FACILITATE LEARNING WITH THE LASER MODEL. Edgar D. Morris, Jr., Div. of Curriculum & Instruction, Va. Tech., Blacksburg, Va. 24061-0313. HyperCard is a computer software that provides its users with a way of expressing themselves textually but with the added dimensions of sound and animation. With one of the major components of George Glasson's and Rosary Lalik's Language and Action in Science Education Reflections (LASER) model being that through language students can represent their point of view, it would seem that Hypercard would be a useful language tool for this endeavor. This study provided an eighth grade physical science class with a Macintosh Classic and Hypercard 2.0 software for the purpose of allowing these students and their teacher an opportunity to use Hypercard in conjunction with the LASER model to see if indeed that Hypercard could aid in facilitating student learning by providing the student with tools to extend their communication of ideas. The results were that both the teacher and students alike found ways of using the Hypercard software for communicating their ideas to others.

A TWO-WEEK SUMMER SCIENCE AND TECHNOLOGY ATTITUDE BOOST FOR NINTH GRADERS.

Alvin M. Pettus, Secondary Education, Library Science and Educational Leadership, James Madison University, Harrisonburg, VA 22807 & Paul Clifford*, Thomas Harrison Middle School, Harrisonburg, VA 22801. Twenty ninth grade students in the Better Information Project attended a two-week Pre-College Awareness session at James Madison University during the Summer of 1990. In addition to addressing the overall purpose of the program as defined by the State Council of Higher Education in Virginia, the program at JMU emphasized learning and enrichment activities related to science, mathematics, and technology. The activities were designed to develop positive attitudes and perceptions about studying science and mathematics in schools and applying science and technology to solve problems in the future. Topics for the enrichment activities included, "DNA: The Stuff of Life," "The Wonders of Liquid Nitrogen," "Investigations of Separations," "The Summer Sky," and "Graphs As Math Models." Positive changes were detected in student participants' attitudes toward studying science and mathematics personally and toward the value of science and mathematics study for others.

INSERVICE PROGRAMS FOR PHYSICS TEACHERS: ANTICIPATED NEEDS AND REAL EXPERIENCES. Thomas G. Teates, Div. of Curriculum & Instruction, & Dale D. Long, Dept. of Physics, VA Polytechnic Inst. & St. Univ., Blacksburg, VA 24061-0313. During a two year period 45 physics and physical science teachers participated in a summer and academic year program designed to provide a thorough knowledge of physics fundamentals, preparation for extensive use of hands-on activities for labs and effective demonstrations, experience with multiple uses of microcomputers and interface devices, knowledge of an array of practical applications of physics in everyday situations, and preparation to lead workshops in their local schools. The authors have been impressed with the many accomplishments of participants and the changes for better science instruction for students and with the difficulty of changing some of the traditional practices and constraints that are imbedded in the school culture and which interfere with the improvement in the quality of instruction. Pleasant surprises and disappointments in the observed teaching situations and practices of participants suggest that positive change is possible but comes slowly and depends on multiple factors at the local level.

HANDS-ON ORGANIC MECHANISMS.

George S. Whitney, Department of Chemistry, Washington & Lee Univ., Lexington VA 24450. Ways of getting students to learn mechanisms are often frustrating, if not futile. This illustrates a method of involving several students to illustrate acyl mechanisms using hands and arms as electron bonds. I'll discuss whether the amount learning equals the amusement value.

Engineering (Business Meeting Only)

Environmental Sciences

LABORATORY ANALYSIS OF SOIL CONDITIONS IN CONSTRUCTED WETLANDS IN VIRGINIA. Robert B. Atkinson, Paul R. Benzing, and J. Cairns, Jr. Ctr. for Env. and Haz. Mat. Studies, Va. Polytechnic Inst. Under section 404 of the Clean Water Act, approximately 40 ha of mitigation sites for forested wetlands have been created and more are planned through 1995. Naturally occurring forested wetlands perform a variety of functions, some of which are related to anaerobic soil conditions. A laboratory study was conducted to determine potential for oxygen depletion and carbon dioxide formation under flooded conditions. Soil samples were taken from constructed wetland, adjacent reference wetland, an adjacent upland, and were paired with sample locations for field analysis of soil redox potential. Soil cores were placed in quart mason jars, covered with distilled water to leave a six cm head space, and sealed. Gas samples were taken weekly and carbon dioxide and methane concentrations were determined using a thermal gas chromatograph. Carbon dioxide production was highest in natural wetland soils and lowest in constructed wetland soils. Indications of methane production were limited to natural wetlands.

FIELD ANALYSIS OF SOIL WATER IN CONSTRUCTED FRESHWATER WETLANDS IN VIRGINIA. Robert B. Atkinson, David S. Barber, and J. Cairns, Jr., Univ. Ctr. for Env. and Haz. Mat. Studies, Va. Polytechnic Inst. In accord with Section 404 of the Clean Water Act, the Virginia Department of Transportation (VDOT) has constructed approximately 40 ha of palustrine forested wetlands. The study site is a 1.5 ha wetland constructed in 1987 in Petersburg, Va. Field investigation of redox potential was designed to compare constructed wetland, adjacent uplands, and an adjacent reference wetland. Redox potentials were measured below water table using platinum electrodes, a saturated calomel reference electrode, and a field meter. Platinum electrodes were constructed by soldering 30 cm of 20 gauge insulated copper wire to 1.3 cm of 20 gauge platinum wire, inserted into a pointed glass tube, and sealed at both ends. Preliminary results indicate significantly higher redox potentials in constructed wetland soils.

THE DEVELOPMENT OF CHEMICAL-DIFFUSING SUBSTRATES FOR IN SITU PERIPHYTON COMMUNITY SURVEYS. Matthew Arnegard, Paul V. McCormick, & John Cairns, Jr., Dept. of Biol., Va. Polytechnic Inst., Blacksburg, Va. 24061. Investigators studying the effects of chemical stress on ecosystems are often faced with a choice between laboratory tests, which tend to lack environmental realism, and field assessments, which lack control and replicability. An in situ experimental method for predicting environmental hazard is discussed which measures impacts on periphyton communities. A chemical stressor contained in a plastic flask diffuses through a porous clay surface and into the periphyton community developing on the outer surface. Initial laboratory trials using various classes of chemicals (e.g., acids, metals) indicate that reasonably predictable rates of diffusion are achieved. This method allows for much of the control and replicability of laboratory tests to be obtained under ambient environmental conditions.

SEDIMENTOLOGY AND STRATIGRAPHY OF SAND SHOALS ON THE VIRGINIA INNER SHELF. Margaret Christina Calvert, Dept. of Environmental Science, Lynchburg College, 1501 Lakeside Drive, Lynchburg, Va. 24501. This study was conducted as a portion of a ten week internship with the Virginia Institute of Marine Science. The purpose was to gain a better understanding of quaternary history of the continental shelf. Vibracore samples were correlated with seismic reflection records to determine shoal morphology.

ACTIVITIES DURING AN ENVIRONMENTAL SCIENCE INTERNSHIP.

Ryan Cilsick, Dept. of Biology, P.O. Box 2121, Lynchburg Col., Lynchburg, VA, 24501. Internship was conducted over the summer of 1990. Summary and description of duties of a Natural History Intern for the Nature Center and Planetarium of Lee County, Ft. Myers, FL. Some of the tasks involved were teaching on elementary level, caretaking of wildlife, (rattlesnakes, bald eagles, alligators, etc) leading fieldtrips, presentations, and guided tours.

COUNTY NATURAL AREAS INVENTORIES IN VIRGINIA. Christopher A. Clampitt, Dept. of Conservation and Recreation, Division of Natural Heritage, 203 Governor St. Suite 402, Richmond, VA 23219. The Division of Natural Heritage is the Commonwealth's principal manager of information on rare, threatened and endangered species and unique or exemplary natural communities (natural heritage resources). The Division has instituted county natural areas inventories to 1) systematically identify natural heritage resources and 2) build partnerships with localities that will lead to greater protection of these resources at the local level. Natural areas inventories are conducted in the following steps: 1) collate existing information from museum collections and literature; 2) review maps and aerial photographs; 3) interview local experts; 4) aerial reconnaissance; 5) field surveys of potential natural areas; and 6) preparation of site reports that include protection recommendations. Efforts are underway to expand joint state/local protection activities and to explore the development of natural heritage resources GIS layers for localities.

A COMPARISON OF GROWTH AND PHOTOSYNTHETIC RATES OF THREE CYANOBACTERIAL SPECIES FROM THE TIDAL FRESHWATER POTOMAC RIVER. James F. Coles, Dept. of Biology, George Mason Univ., Fairfax, Va. 22030. Frequently throughout the 1980's, seasonal blooms of cyanobacteria (blue-green algae) occurred at nuisance levels at the Gunston Cove region of the Potomac River near Washington, D.C. The species which has been most dominant and consequently responsible for the blooms is Microcystis aeruginosa. This species, and two other cyanobacteria, Merismopedia and Oscillatoria, were isolated from Potomac River water samples and grown in artificially enriched media which simulates eutrophic conditions. Using the ^{14}C Tracer technique, photosynthetic rate curves for each species were determined at the temperatures of 15 $^{\circ}$, 20 $^{\circ}$, 25 $^{\circ}$, 30 $^{\circ}$ Celsius. A consistent trend in the curves of all three species suggests that photo-inhibition tends to occur at lower light intensities at lower temperatures. Additionally, growth rates of the three species were determined at each of the four temperatures by measuring chlorophyll-a concentration over time. By comparing the changes in cell density with that of chlorophyll concentration of Microcystis, it was observed that the chlorophyll content per cell increases when the culture is grown at higher temperatures, suggesting that chlorophyll concentration as a measure of biomass is temperature dependant.

DETERMINING COMMUNITY STRUCTURE SIMILARITIES BY STUDYING SPECIES DIVERSITY IN SHALLOW WATER AREAS ON LAKE GASTON. Chad R. Coley, Dept. of Biol., Lynchburg College, Lynchburg, Va. 24501. A species diversity study was conducted on Lake Gaston in the summer of 1990 to correctly identify species located there and to conclude community similarities. Ten different areas were observed: five lentic and five lotic environments. Each area was visited at dawn and at dusk to draw time variations of fish species. A relative abundance graph was constructed showing abundance or rarity of each species collected. A pie distribution table assorted nine fish families to percentage groups representing the entire catch. Simpson's Index with other indices were used to measure diversity for community structure. Community similarities were evident among lentic and lotic environments. Species were found to be more evenly distributed in still water where running water areas were conservative in species represented. Predacious species were found more evident at dusk. The minnow and perch families were the dominant representatives while other bait fish were also seen to be rather abundant.

EVALUATION OF AN ION SELECTIVE ELECTRODE FOR THE DETERMINATION OF CUPRIC ION IN FRESHWATER. Claudia Hamblin-Katnik, Dept. of Biol., George Mason Univ., Fairfax, VA. 22030. The cupric ion selective electrode (Orion 94-29) can be utilized to measure cupric ion content within fresh waters with some limitations. To achieve valid measurements, particularly at ionic concentrations of less than 10^{-5} , control of many parameters must be rigorously maintained throughout the sample preparation and measurement process. Parameters which must be considered are electrode cleanliness, equilibration, constant ionic strength, pH, temperature, sample volume, light, continuous stirring, use of metal-ion buffers, electrode placement during measurement, preconditioning and calibration. If constancy is not maintained in all areas a true Nernstian response can not be achieved.

A COMPARATIVE ECOFLORISTIC ANALYSIS OF THREE HIGH ELEVATION SPRINGS IN THE CENTRAL VIRGINIA BLUE RIDGE MOUNTAINS. Catherine G. Hnat, Teresa M. Nuckols, Terry L. Parrotte, Dept. of Biol., Lynchburg College, Lynchburg, Va. 24501. The first phase of a study of three high elevation springs in the central Virginia Blue Ridge Mountains-Wiggins spring 3160 ft., Armstrong spring 3580 ft., Lovington spring 3690 ft.-has shown dissolved oxygen levels at 10 mg/L to 12 mg/L and Ph levels averaging from 4.6 to 5.0. Continuing phases of this study will help to determine how these and other ecological characteristics, rather than just the high elevations, influence the floristic differences found at these springs.

COMPARISON OF FLORIDA AND NORTHERN SUBSPECIES OF LARGEMOUTH BASS IN BRIERY CREEK LAKE, VIRGINIA. Randall S. Hoover, John J. Ney, and Eric M. Hallerman.* Dept. of Fisheries and Wildlife Sciences, Va. Polytechnic Inst. and State Univ., Blacksburg, VA 24061.

Briery Creek Lake, a 342-ha reservoir in south central Virginia, was stocked with both Florida and northern subspecies of largemouth bass following impoundment in 1986 and again in 1987. Both subspecies were stocked concurrently to permit evaluation of the potential of Florida bass to provide a trophy fishery in Virginia. We compared population composition, condition factor (a weight versus length metric), and growth rate for the 1987, 1988, and 1989 year classes of northern (N) and Florida (FL) bass and their hybrid progeny (F_1 and F_2). Geneotypes were differentiated in more than 400 bass by enzyme electrophoresis at four loci (A at-B, Gal-B, Idh-B, and Sod-A) which served as genetic markers.

Composition of all three year classes was dominated by hybrids (average of 73% F_1 and 13% F_2 fish), indicating probable genetic impurity in parental stocks. Florida bass and F_1 hybrid had consistently higher condition factors than did northern bass. However, growth rates as estimated from length at capture did not differ significantly among the four groups.

SPATIAL, SEASONAL, AND INTERANNUAL PATTERNS IN PHYTOPLANKTON DENSITY AND TAXONOMIC COMPOSITION IN THE TIDAL FRESHWATER POTOMAC RIVER. R. Christian Jones, Claire Buchanan, and Victoria Andrele, Dept. of Biology, George Mason University, Fairfax, VA 22030. Phytoplankton were enumerated by species on samples collected on a biweekly to monthly basis over 6 years from 11-13 sites on the tidal freshwater Potomac River. Cell densities were analyzed by analysis of variance examining spatial, seasonal, and interannual variability. Phytoplankton densities were higher in the two embayment areas than in the river mainstem. A nearly exponential increase in phytoplankton was observed from March through August with a rapid decline in September and October. This pattern differed significantly among years resulting in a significant month-year interaction. Differences among years was also significant with the two lowest years correlating with low water residence times. Loss processes, particularly flushing, seemed to be generally more important than growth processes in explaining seasonal and interannual variation. Both growth and loss factors contributed to spatial variation. Diatoms were dominant in spring and various cyanobacterial species were most important in summer.

WHAT CAN THE VIRGINIA MUSEUM OF NATURAL HISTORY AT VPI&SU OFFER TO STUDENTS, TEACHERS, SCIENTISTS AND THE PUBLIC. Michael Koszta, Virginia Museum of Natural History, 428 N. Main St. Blacksburg, VA, 24061-0542. This young museum houses the oldest (initiated in 1888) and largest (ca. 920,000 specimens) natural history collections in the Commonwealth. Only the four zoological collections are housed in the new museum building. The three botanical collections as well as the paleontological and geological collections are in the Departments of Biology and Geology (Derring Hall) respectively.

Our first exhibits "Diversity Endangered" and "Mammals of North America" were very well received by the public. They averaged 1,000 visitors monthly during the first two months, and now are being moved to the main museum in Martinsville. Our newest exhibit, "Wildlife Endangered" includes color photographs on Virginia wildlife by Lynda Richardson of Richmond. A public lecture and field trip series was initiated with such topics as "How Birds Survive the Winter," and "Bats," with more to come. Our museum scientists are available to provide slide-illustrated talks for organizations and schools, and during the past ten years they have produced 418 publications and supervised 67 graduate students.

SMALL MAMMAL OCCURRENCE AND HABITAT ASSOCIATIONS IN A SUBURBAN ENVIRONMENT. Jill H. Kruper & T. L. Derting, Dept. of Biology, Hollins Col., Roanoke, Va. 24020. Within a suburban setting a large amount of human disturbance occurs which affects habitat availability and its characteristics. Consequently, the animal diversity within such areas is reduced. Identification of habitat characteristics that are essential to small mammal existence could improve landscape management practices which promote species retention. In this study, small mammal species occurrence was determined in disturbed (mown) and undisturbed field and wooded habitats in a suburban area. Habitat variables measured were vertical and ground cover, vegetation composition, and soil characteristics. Animal abundance and species richness was greater in the undisturbed field (85 animals, 5 spp.) than in the disturbed field (9 animals, 2 spp.). Occurrence was highest in areas with greatest vertical (< 0.5 m) and ground cover. In wooded areas, species richness and abundance decreased as disturbance increased (66 individuals, 5 spp. to 2 individuals, 1 spp.). Animal occurrence was positively associated with % vertical cover (> 0.5 m), litter depth, and plant spp. diversity. Thus, emphasis on the preservation of vegetative cover may be of key importance to enhancing small mammal species diversity in suburban areas.

A THREE MONTH STUDY OF FECAL COLIFORM LEVELS FROM THREE AREAS OF SMITH MOUNTAIN LAKE, VIRGINIA. Stuart R. Lynde & O. O. Stenroos Ph.D., Dept. of Biol., Lynchburg College, Lynchburg, Va. 24501. A three month fecal coliform study during the summer of 1990, consisting of biweekly samplings of lake water at Smith Mountain Lake, Virginia revealed levels of contamination below the fecal standard. Studies indicated an overall correlation to rainfall possibly resulting in drainage of coliforms from the soil. Limited direct sewage input into the system was also noticed, possibly the result of boat spillage. The contamination seemed to be widely distributed throughout the lake, as demonstrated by comparable fecal coliform levels from three distinct locations. These levels, however, were directly linked to the increased summer human population and either greatly declined or disappeared after the Labor Day weekend, corresponding to the decline in human population surrounding and using the lake. (Supported by the Smith Mountain Lake Association.)

TREATMENT OF RADON RICH WELL WATER. Douglas Mose, George Mushrush and Charles Chrosniak, Center of Basic and Applied Science, George Mason University, Fairfax, VA 22030. Private wells supply potable water to about 25% of the homes in northern Virginia, and almost all water wells contain radon, a carcinogenic radionuclide derived from uranium in rocks and soil. The average Virginia well provides about 2000-3000 pCi/l of dissolved radon; the U.S. Environmental Protection Agency has proposed that 300 pCi/l should be the allowed maximum for public water supplies. To estimate the ability of activated charcoal to remove radon from private well water, a home supplied by a water well carrying @4000 pCi/l was studied. Following 1 year of water measurements, an in-line tank containing 1 cubic foot of activated charcoal was installed, and a subsequent 6 month interval of radon measurements on untreated and on treated water was conducted. Although removal rates of more than 90% have been reported, this study home showed a 60-70% radiation removal in the tank. A high percentage removal rate was reached in less than a month after installation, and was maintained for about 4 months, but the removal rate declined to about 50% by the end of the testing interval. Additional studies are being conducted to determine the effect of using different charcoal volumes, different charcoal types; also being studied is the gamma emission of the charcoal tank.

RESEARCH IN PERCEPTIONS OF GLOBAL CLIMATE CHANGE. Katherine E. Spencer, Dept. of Biology, Lynchburg Col., Lynchburg, VA 24501. This project deals with research on global climate trends which have been observed in the twentieth century. Issues of global warming, global cooling, and causes will be addressed. The effects of global warming on the Earth's ecosystems and the well-being of humans will be examined. Causal agents of global warming will be analyzed in terms of their impact on other environmental issues, such as ozone depletion and human health. Results will address possible approaches to these issues in the future.

A SIX MONTH INVESTIGATION AND ANALYSIS OF THE WATER QUALITY OF COLLEGE LAKE. Greg Ware, and Ryan Cilsick, Dept. of Biol., Lynchburg Col., Lynchburg, VA 24501. This project deals with the collection and analysis of "grab" water samples from four specific locations on the shores of Lynchburg College Lake determining its water quality. The observations and the data obtained through a well planned and executed monitoring program will provide interesting information to Lynchburg College Officials and to those individuals interested in proper sampling techniques and analytical methods performed. Over a period of six months water was collected on a weekly basis and analyzed for the contamination of volatile organic compounds by gas chromatography, pH, specific conductance, fecal coliform, total organic carbon, chemical oxygen demand, temperature, suspended solids, and various metals by atomic absorption spectroscopy (AA). Results will be discussed determining the possible sources of detected contamination and indicating the threat these contaminants could have on the college lake ecosystems.

Geology

EXPERIMENTAL PARTIAL MELTING OF PEDLAR CHARNOKITES, VIRGINIA BLUE RIDGE. J. S. Beard, Virginia Museum of Natural History, Martinsville, VA 24112; G.E. Lofgren, SM2, NASA/JSC, Houston, TX 77058; A. K. Sinha, Department of Geological Sciences, VPI/SU, Blacksburg, VA 24061. Several charnockitic gneisses from the Pedlar Massif of the central Virginia Blue Ridge were experimentally partially melted ($P=700$ MPa, $T=850-950^{\circ}\text{C}$, $\text{NNO}<f_{\text{O}_2}<\text{HM}$) and, with one exception, yielded substantial (24-58%) melt by 900°C . The low-temperature melts of charnockitic gneisses are peraluminous and granitic ($\text{Na}_2\text{O}/\text{K}_2\text{O}=.36-.55$; $\text{SiO}_2=73-75\%$). With increasing temperature, the melts become less granitic and are enriched in Fe, Ti and P. The melts coexist with the solid phase assemblage $\text{ksp-mt-il-opx-apat-qtz-zircon}$. Subhedral to euhedral apatite that is in apparent textural equilibrium with the liquid is present in nearly every charge (usually 0.3 to 1.0% by weight). Apatite is strongly enriched in REE and Y. In the subsolidus assemblage of the charnockites, an average of 20-30% of the total La and Ce, over 50% of the Nd and nearly 80% of Y is contained in the apatite. At the same time, Eu is presumably strongly partitioned into restitic potassium feldspar. This implies that granitic melts derived from charnockitic Grenville basement will have steep, strongly LREE-enriched patterns with large negative Eu anomalies. Models based on the measured REE contents of apatite and charnockite and on the high-temperature melting and phase relations of the charnockites can reproduce many aspects of the major element and REE chemistry of some late Proterozoic subalkaline granites, suggesting a major role for melting of charnockitic crust in the petrogenesis of these granites.

POTENTIAL CHEMICAL STABILIZATION OF A SOIL FROM CATAWBA MOUNTAIN, VIRGINIA. David A. Hubbard, Jr.*, Va. Div. Mineral Resources, P.O. Box 3667, Charlottesville, VA 22903. James D. Behmer, Civil Engrn., Univ. Va., Robin Grossman*, Civil Engrn., Univ. Va., H. Gordon Larew*, Civil Engrn., Thornton Hall, Univ. Va., Charlottesville, VA 22903. Numerous landslides exist along the flanks of Tinker Mountain and its southern extension Catawba Mountain. The landslide prone soils are developed on interbedded limestone and shale of Late Ordovician-age. Soil sampled from Catawba Mountain was classified as MH, for engineering purposes. The physical and mechanical soil properties are influenced by the clay mineralogy, characterized as a illitic-chloritic mixture. The soil was chemically treated with one of three chloride salts or lime to evaluate its mechanical response for potential stabilization. Both CaCl_2 and lime were found to enhance shear strength for four- and 28-day cured samples. Unfortunately, these test results conflict with test data from an engineering study at the lithologically and pedologically similar Hollins landslide site on Tinker Mountain. Variability in the composition and properties of illite soils indicate the importance of site specific characterization and stabilization studies for engineering solutions to landslide hazards.

CORRELATION OF WELL LOGS FROM THE SUBSURFACE OF WEST VIRGINIA USING RELATIVE SEA-LEVEL CURVES. Brett T. Brodersen, Richard J. Diecchio, George Mason Univ., Fairfax, Va. 22030. Relative sea-level curves were generated from gamma-ray and neutron logs for three deep wells in West Virginia, penetrating Mississippian to Cambrian strata. Deflections on the logs were interpreted as sandstone-shale or limestone-shale couplets. Sea-level curves were generated from these data using a technique similar to the method used to generate Fischer plots. In an attempt to evaluate this technique, these plots were compared to one another as well as to other published sea-level curves.

Major sea-level lowstands and highstands were correlated from well to well. Sea-level lowstands associated with the top and bottom of the Tippecanoe Sequence are discernable along with the a major lowstand at the end of the Ordovician. Third-order cycles throughout the Devonian, Silurian, and Ordovician are also discernable from the relative sea-level curves and many of these coincide with cycles recognized by other workers.

CATION EXCHANGE BETWEEN SEDIMENTS OF THE KIAMICHI FORMATION AND SALINE WATERS OF DOUBLE LAKE, WEST TEXAS. Terry Councell, Dept. of Geog., George Mason Univ., Fairfax, Va. 22030 and Warren Wood*, U.S. Geological Survey, Reston, Va. 22092. Double Lake is a saline lake situated on top of Cretaceous sediments of the Kiamichi Formation on the Southern High Plains of Texas. Observation wells were installed along the regional ground water flow gradient. One well just up-gradient of the lake (CE-1) contains anomalously high values of Ca and Mg. Two processes could explain these findings: cation exchange between Na in the lake water and Ca and Mg in the clays; and dedolomitization of deeper sediments. To test the hypothesis, sediment samples from vertical sections were analyzed for exchangeable cations. Well CE-1 penetrates the fresh/saline water mixing zone. Analysis of exchangeable cations in sediments from the freshwater section of CE-1 showed low Na values, similar to results of sediments upgradient of the lake. This evidence, combined with anomalously high Ca and Mg values in the water, suggest that cation exchange is occurring in Kiamichi sediments, whereby Ca and Mg are being liberated from clays by cation-exchange with Na in the water.

REPTILE LINEAGES ACROSS THE TRIASSIC-JURASSIC BOUNDARY OF VIRGINIA.

Nicholas C. Fraser, Virginia Museum of Natural History, Martinsville, VA 24112. The end of the Triassic was a key period in the evolution of terrestrial vertebrates. The first crocodiles, chelonians, sphenodontians, modern amphibian taxa, mammals and possibly also the earliest birds are known from Middle to Late Triassic sediments. In addition the first dinosaurs and pterosaurs also date back to this time interval. At this time Virginia lay at the heart of the supercontinent Pangaea, joined to what is today North Africa. Major mass extinctions are thought to have occurred at the end of the Triassic, but the exact nature and timing of these is disputed. Recent research on Triassic sediments in Virginia has centered on extensive new fossil reptiles. The new evidence indicates that there was a major mass extinction at the close of the Norian stage. There is also some indication that certain early Mesozoic tetrapods are useful biostratigraphically.

THE JAMES MADISON UNIVERSITY MINERAL MUSEUM. Lance E. Kearns, Dept. of Geol./Geog., JMU, Harrisonburg, Va. 22807. The Mineral Museum which was initiated in 1976 is located on the top floor of Miller Hall. The collection presently displays over 700 specimens. The growth of the collection has been attributed to major donations by the Univ. of Del. and Bryn Mawr College in the late 1970s along with extensive private donations from mineral collectors, mineral dealers, and private individuals. The museum displays a systematic collection, an oversized specimen display, a suite of minerals from Elmwood, Tenn., a fluorescent mineral display from Franklin, N.J., and the recently endowed R.S. Mitchell Memorial Virginia Mineral collection.

GEOLOGY OF SMITH MOUNTAIN LAKE STATE PARK. W.S. Henika, Va. Div. of Mineral Resources, Dept. of Geol. Sci., Va. Polytechnic Inst. and State Univ., Blacksburg, Va. 24061. The Smith Mountain Lake State Park is in the southwestern Virginia Piedmont along the southeastern flank of the Blue Ridge anticlinorium. The area is one of intensely deformed metamorphic rocks of volcanic, sedimentary and igneous origins and is located about 5 miles southwest of the Bowens Creek wrench fault zone. The northwestern portion of the park is underlain by a layered biotite-hornblende gneiss unit (Moneta Gneiss/Ash Fm.) whereas southeast of the central boat launching area is a metagreywacke gneiss unit with thin actinolite schist, graphitic mica schist, calcareous gneiss and quartzite interbeds (Lynchburg Fm./Alligator Back Fm.). A large mafic/ultramafic pluton is along the southeastern park boundary. Map distribution of rock types shows regionally significant fold structures and controls important engineering properties of residual soil profiles affecting septic tank/drain field system locations and shore line erodability in the park area. Copyright Commonwealth of Virginia, 1991.

THE EFFECTS OF GROUNDWATER LEACHING ON FOSSIL PRESERVATION IN THE YORKTOWN FM.

J. D. Herman, Dept. of Geol., James Madison Univ., Harrisonburg, Va. 22807. Patterns of fossil diagenesis caused by groundwater leaching provide insight into how shells are altered in unconsolidated terrigenous sediments on the Virginia coastal plain. The vertical and lateral distribution of diagenetic states was mapped in an outcrop of the Yorktown Formation (Upper Pliocene). At one end, a paleostream channel was incised during the Pleistocene and filled with sediments of the Shirley Formation. Groundwater movement, controlled by the presence of the paleochannel, caused patterns of fossil and sediment diagenesis.

Acidic groundwater caused diagenetic alteration or complete dissolution of fossils, and precipitated fine-grained iron oxyhydroxides. All carbonate material in the vicinity of the paleochannel was completely dissolved away, although ghosts of fossils remain. Away from the paleochannel, calcitic and aragonitic shells are found in parallel zones of alteration that dip toward the paleochannel and cut across original horizontal sedimentologic and fossiliferous layers. Groundwater leaching also produced a diagenetic stratification of the sediment, resulting in mineralogic and color changes.

The preservation of both aragonitic and calcitic shells was affected. Original aragonitic shells are found as chalky, unrecrystallized specimens, as neomorphosed shells, or are completely dissolved away. Original calcitic shells are either unaltered or chalky. Chalky shells range from relatively hard to soft and pasty, and SEM photos suggest that chalkiness is caused by dissolution of shell material and not simply loss of organic matrix. The presence of chalky aragonitic and calcitic shells indicate that chalky textures are, to some degree, independent of mineralogy and microstructure.

THE USE OF AQUIFER HYDROLOGY, CLIMATOLOGICAL VARIABLES, AND ESTUARINE SALINITY TO PREDICT SALTWATER INTRUSION INTO THE NORTHWEST RIVER NEAR CHESAPEAKE, VIRGINIA.

Vaughan Mairs and H.G. Goodell, Dept. Environmental Sciences, University of Virginia, Charlottesville, VA 22903. The City of Chesapeake draws up to 10 MGD of water for domestic purposes from the Northwest River, a tributary of Currituck Sound. The river receives its base flow from the near surface aquifer of the Lynnhaven member of the Tabb Formation. In times of deficient precipitation the water table falls, the river discharge declines, and brackish estuarine water intrudes up the channel to the city's water intakes at the crossing of VA Routes 168 and 17. Precipitation, aquifer water level, and estuarine salinity data have been used to develop a predicting equation for water quality at the intakes. A stochastic model has been developed which predicts the time lag before the water supply exceeds a threshold of 250ppm chloride.

SOILS IN THE GEOLOGY CURRICULUM. W. C. Sherwood, Geol. and Geog. Dept., James Madison Univ., Harrisonburg, VA 22807.

The rapid increase in employment opportunities for geologists in hydrogeology and engineering geology has created demand for courses emphasizing surficial geology and surface processes. At JMU, a junior level course titled "Soils and Land Use" has been offered each fall since 1975. Over the 16 years average enrollment has been 28.5 students with a range of 15 to 38, making it our most popular junior level offering in geology. Course content is divided into 4 major topics - Classification and Distribution, Geochemistry and Mineralogy, Engineering Properties, and Land Use. Labs include: estimation of soil textures, grain size analysis, x-ray diffraction identification of common soil clays, Proctor test for optimum moisture and maximum density determination, and use of the Universal Soil Loss Equation for soil loss prediction. Field trips are conducted in the Valley and Ridge and Piedmont where approximately 10 of the most common soils in each area are augured and examined. The course is integrated closely with our offerings in geomorphology and geohydrology. It also serves as a prerequisite for Engineering Geology. The combination of the soils and engineering geology courses provides the student with a background in soil mechanics approaching that offered in a one semester course in traditional civil engineering programs. At JMU, a new Environmental Studies minor has incorporated Soils and Land Use as one of the options in the natural sciences, so that demand for the course continues to increase.

THE GEOMETRY AND GENESIS OF FAULTS IN PAGE COUNTY, VIRGINIA. Michael J. Sarros, Dept. of Geology, Old Dominion Univ. Norfolk, Va. 23529. Recent field work indicates Cambrian-Ordovician carbonates in Page Valley south of Luray are displaced by three major faults. The oldest of these faults thrusts the Cambrian Conococheague Formation over the Ordovician Beekmantown Formation. This fault is folded by a broad anticline which is truncated by a NW striking low angle thrust tentatively named the Honeyville fault. The Honeyville fault may be correlative with the Sedwick fault mapped to the north by Hill (1988). It offsets the Beekmantown Formation by approximately 1500 meters. One mile to the east Cambrian clastics of the Blue Ridge and Cambrian-Ordovician carbonates of Page Valley are offset nearly 3300 meters by the Stanley fault. The Stanley fault is a steeply dipping fault which exhibits both dextral and strike-slip motion. Associated with these faults are mesoscopic structural features including well developed cleavage, folds, sigmoidal veins, boudinage, lineations, and fault breccias. Folded cleavage and cross-cutting cleavages indicate multiple stages of deformation in the Late Paleozoic.

THE JOHN FINCH COLLECTION OF TERTIARY MOLLUSKS IN 1824 AND ITS SIGNIFICANCE TO PALEONTOLOGY AND GEOLOGY. Lauck W. Ward, Virginia Museum of Natural History, Martinsville, VA 24112. The first important paper on invertebrate paleontology in the new world was written by Thomas Say in 1824 and described new species of mollusks. Say's paper was based on a collection of fossils made by visiting Scottish geologist John Finch. Finch bestowed his collection of Tertiary coastal plain mollusks on the members of the Academy of Natural Sciences of Philadelphia (ANSP). Besides Thomas Say, T.A. Conrad, Issac Lea, S.G. Morton and Jacob Green received fossils for description. Mysteriously, these mollusks were described as being found in Maryland, but few of the specimens occur in strata of the age found in Maryland. A biostratigraphic study of the assemblage reveals that they are of late Miocene and Pliocene age and involve taxa typical of the Eastover and Yorktown formations in Virginia. Finch (1833) described a collecting trip on the St. Mary's River in Maryland, but he also discussed in detail the geology and shell deposits at Yorktown, Virginia. Yorktown is believed to be the type area for all the mollusks left by Finch at the ANSP. The confusion of these localities has led to long-standing nomenclatural confusion in which the Pliocene fossil names have been improperly applied to Maryland Miocene taxa.

LOCATING A GROUNDWATER SUPPLY IN THE ROME FORMATION FOR ELLISTON, VIRGINIA. Chester F. Watts, Institute for Engineering Geosciences, Dept. of Geology, Radford University, Radford, Va. 24142. In September of 1990, the Virginia Department of Health ordered the Montgomery County Public Service Authority to advise all customers receiving water from the Elliston Spring to boil water for 10 minutes before use. This was based on wide fluctuations in both turbidity and bacteriological quality. Those indicators, plus the quick response of the spring to heavy precipitation, indicate a groundwater system strongly influenced by surface water. At the request of the Public Service Authority, the author conducted a geologic study with the intentions of: (1) identifying the spring's recharge area; (2) locating the source(s) of bacterial contamination; and, (3) identifying potential new water supplies for Elliston on property owned by the Authority. Objectives 1 and 2 were met with little difficulty. The bacteria appear to originate with farm animal activity in a marshy area near the spring. Complex geology has made objective 3 more difficult. The property is located within the Rome Formation, which consists of interlayered shale, fine sandstone, siltstone, mudstone, and varying amounts of fine-grained limestones and dolomite. Although the formation is mostly shale and does not conduct water well, the limestone, dolomite, and sandstone lithologies can act as water conduits thereby playing a significant role in spring formation. The spring also lies near the central axis of a syncline plunging steeply toward the southeast and cut by a series of fractures. In that the Health Department strongly favors phasing out springs as water supplies, the author located three sites for test wells, presumably into conductive zones on the property. At this time, one of the test wells has been drilled and it failed to produce the 200 gpm needed by the community. Drilling of the two remaining test wells is pending.

PARASUCHIAN OCCURRENCES IN UPPER TRIASSIC ROCKS OF THE CULPEPER BASIN OF VIRGINIA AND MARYLAND. Robert E. Weems, MS 928, U.S. Geological Survey, Reston, VA 22092, and Calvin R. Wiggs, HydroGeoLogic Inc., 1165 Herndon Parkway, Suite 900, Herndon, VA 22070.

Bones and teeth of parasuchians (crocodile-like archosaurian reptiles) are known from three sites in the Triassic sedimentary section of the Culpeper basin: 1) Manassas Sandstone (fluvial facies) at the intersection of Willard Road and River Road, Montgomery Co., Md.; 2) lower Balls Bluff Siltstone (fluvial facies) at Dulles Airport, Fairfax Co., Va. (Weems, 1979, Proc. Biol. Soc. Washington 92(4):682-688); and 3) middle Balls Bluff Siltstone (lacustrine facies) in the Culpeper Crushed Stone Quarry, Stevensburg, Culpeper Co., Va. The River Road specimen, a dentary with teeth, is the best available, but it is still inadequate to identify a specific genus. The palynologically determined early Norian age of all these specimens, however, circumstantially supports the possibility that they may represent a post-Rutiodon taxon. All of these occurrences are far below the presently accepted Triassic-Jurassic boundary within the basin.

GEOLOGIC HAZARDS IN WESTERN VIRGINIA: THE PRICES FORK ROAD LANDSLIDE, SPRING, 1987. Robert C. Whisonant, Dept. of Geol., Radford Univ., Radford, VA 24142 & Gary K. Rogers, Vecellio and Grogan, Inc., Beckley, WV 25802. In Spring, 1987, a landslide occurred along Montgomery County Road 659 (Prices Fork Road) in the western Virginia Valley and Ridge Province. The failed slope has a history of instability that extends back at least into the early 1900's. It is located in a tectonically disrupted zone associated with the western end of the Price Mountain Window. The rocks here constitute a "fault chaos"; allocthonous blocks of at least nine different stratigraphic units, ranging from Cambrian Copper Ridge sandstones to Mississippian Maccrady shales, have been identified in the chaos (Schultz, 1979). Extremely poor foundation conditions result. In addition to the geological setting, contributing factors to the Spring, 1987, landslide include: (1) construction of Prices Fork Road (adding weight to the slope and increasing the runoff); (2) removal of lateral support at the base of the slope by railroad construction; and, (3) excessive recent rainfall causing elevated pore-water pressures. Attempts to stabilize the slope include regrading of the slide mass, construction of a tieback wall, and minor redirection of surface runoff. These remedial efforts have been successful to the present.

GEOLOGIC AND HYDROLOGIC CONTROLS OF WATER TABLES ON REGRESSIVE BARRIER ISLANDS. G. Richard Whittecar and Chris J. Johnson, Dept. of Geol. Sci., Old Dominion Univ., Norfolk, VA 23529. Progradation of beach and nearshore facies on a barrier island forms a surficial aquifer that is often mostly coarsening upwards. At two such regressive barrier features - Cape Henry, Virginia and Bodie Island at Kitty Hawk, N.C. - the surficial aquifer is generally 15 to 20 meters thick. On barrier islands, the water table shape is a function of barrier geometry and hydraulic conductivity, the recharge rate (mostly precipitation minus evapotranspiration), and the evaporation rate from wetlands and ponds. Water table profiles across areas with no surface water display broad symmetric domes. According to analyses of 2-dimensional ground-water flow models, deviations from this ideal shape occur where evaporative losses are significant. At Cape Henry the water table is strongly asymmetric, apparently due to losses from extensive fresh water swamps in the southern half of the area; at Kitty Hawk, asymmetry occurs across a zone of intertidal ponds and around a large reservoir in the middle of the island. Monthly recharge rates are estimated via water budget calculations based upon Thornthwaite formulae. Using a time-weighted average, from 18 to 36 months of recharge values are needed to calculate the "effective recharge" for a given month.

Materials Science

CONSIDERATIONS OF THE CONFORMATIONAL MULTIPLICITIES IN THE PARTITION FUNCTION FOR A LONG ALIPHATIC CHAIN. R. E. Barker, Jr.¹ and Amarjit J. Mahajan², ¹Dept. of Materials Science and ²Dept. of Chemical Engineering, University of Va., Charlottesville, Va. 22903-2442. As any material approaches equilibrium in the statistical mechanical sense the statistical units of the system will establish a dynamic steady state that is determined by two types of factors: the Boltzmann terms $B_j = \exp(-E_j/kT)$ and the statistical weights (multiplicities) W_j for each member of the set $\{j\}$ of possible distinct states. The link to thermodynamics is through the partition function $Z = \sum B_j W_j$. The object of this research is to consider the W_j 's associated with the way trans, gauche(+) and gauche(-) conformational states are distributed in aliphatic chains $C_n H_{2n+2}$. Following a discussion of the general principles specific numerical examples will be considered for $C_5 H_{12}$ and $C_{20} H_{42}$.

ANALYSIS OF THE FRACTURE OF AN AIRCRAFT WING, D.A. Meyn and R.A. Bayles, Code 6327, Naval Research Laboratory, Washington, DC 20375 The separation of an aircraft wing in flight, a very rare occurrence, resulted in a concentrated effort to ascertain what caused the wing to separate and whether the cause involved an inspectable flaw, such that others of the same type could be inspected, repaired if necessary, and returned to operations. Initial analysis indicated that fracture of the lower wing panel (skin), at a point just outboard (toward the wing tip) of the fuselage attachment, had caused catastrophic fracture of the entire left wing from the rest of the aircraft. The lower panel is the major tensile structural element of the wing, consisting of aluminum alloy plate with integrally machined stiffeners, supporting the weight of the fuselage during flight. The origin of fracture was at first ascribed to fatigue initiating at a fastener hole near the aft edge of the panel in the full-thickness part of the plate. Analysis of the cause of failure based on fatigue initiation in this area was well underway, with unsatisfactory results, when subsequent re-examination proved that although fatigue cracks had indeed initiated at this fastener hole, fatigue initiating at a hole closer to the aft edge of the panel, in an area of greatly reduced thickness not considered part of the main load carrying section, had propagated into the thicker section and overtaken the first-discovered crack. The process of discovery and fracture analysis and the characteristics of the actual origin of fracture which initially masked its importance are described. Examination of other aircraft for cracks in this area forestalled future recurrences of this type of incident. (Supported by Naval Air Systems Command)

FATIGUE CRACK PROPAGATION IN MECHANICALLY ALLOYED AL-4Mg-1.3Li. Gary H. Bray, Dept. of Materials Science, Univ. of Va., Charlottesville, Va. 22903. Fatigue crack growth tests were performed on C(T) specimens at stress ratios of $R=0.1, 0.4, 0.6$, and 0.8 using the K-decreasing test method. The thickness of the specimens exceeded ASTM requirements for plane-strain. The crack growth rates at low stress ratios were higher than those in conventional I/M aluminum alloys due to a paucity of crack tip shielding mechanisms. The crack growth rates at high stress ratios were comparable to those in conventional I/M aluminum alloys. Closure levels increased with increasing stress ratio indicating that plasticity-induced closure contributed significantly to closure at high stress ratios even under plane-strain conditions. Single tensile overloads were applied at $R=0.1$ over a range of baseline ΔK . The maximum retardation in crack growth rate following the overload occurred immediately in contrast to conventional aluminum alloys which typically exhibit delayed retardation.

DETERMINATION OF SENSITIZATION LEVELS IN 304 AND 304L STAINLESS STEELS. Michelle A. Gaudett & J.R. Scully, Dept. of Materials Science, UVA, Charlottesville, VA 22903. Stress corrosion cracking (SCC) of components in nuclear reactors is a reliability concern. The primary cooling systems in commercial reactors are constructed using AISI 304 stainless steel. The heat affected zones of these steels become sensitized during welding and these regions become susceptible to intergranular stress corrosion cracking (IGSCC). The ability of a crack to propagate through a structure is intimately related to the number and distribution of sensitized grain boundaries in the material. Therefore, we need to determine the distributions of sensitization levels of individual grain boundaries for certain "average" or macroscopic values of sensitization. Sensitization levels of 304 and 304L stainless steel will be determined by electrochemical potentiokinetic repassivation tests (EPR) and a method for performing EPR on individual grain boundaries will be developed. The resulting information will be useful in a newly developed computer simulation of IGSCC and enable the prediction of structural lifetimes.

HYDROGEN ENVIRONMENT EMBRITTLEMENT IN β -TITANIUM ALLOYS.

Lisa M. Hartman and R. P. Gangloff, Dept. of Mat. Sci., UVA, Charlottesville, VA. 22903. The goal of this research is to define the conditions and associated mechanisms for Hydrogen Environment Embrittlement (HEE) of advanced high strength β -titanium alloys in marine environments. We hypothesize that HEE is promoted by interactions of occluded crack electrochemistry and dynamic plastic strain that destabilize the protective film at the crack tip and enhance atomic hydrogen production and/or uptake efficiency. Computer controlled fracture mechanics experiments were designed to explore this notion, including: 1) slow rate loading with crack tip strain rate as the controlling variable, and 2) high frequency small amplitude ("ripple") cyclic loading superimposed on a constant or slowly rising load. The ripple load amplitude will subject the crack tip surface to high plastic strain, but will be below the threshold level required for bulk plastic zone fatigue damage. A new β -titanium alloy, Beta 21S (Ti-15Mo-3Nb-3Al by wt%), will be studied. Initial results will be presented for high strength HY130 steel (Fe-5Ni-0.5Cr-0.5Mo-0.1C) in 3.5% NaCl with applied cathodic polarization at -1000 mV_{SCE}. Monotonic loading promoted HEE in this resistant steel, however, ripple cycling at constant load did not induce crack growth.

EXPERIMENTS TO COMPARE SPACE CHARGE DISTRIBUTIONS IN DIELECTRIC LIQUIDS CONTAINING ANISOTROPIC IONIC ADDITIVES. David B. Holt¹, Faith B. Jung-hans, and R. E. Barker, Jr.², ¹Dept. of Chem. and ²Dept. of Mater. Sci., University of Va., Charlottesville, Va. 22903-2442. Distributions of ions in otherwise insulating liquids are of practical relevance in several fields, e.g., in transformer fluids and in biophysical phenomena. Techniques, circuits, and apparatus have been developed to probe the local electrostatic potential $\phi(x)$ in representative liquids to which known concentrations of molecular ions have been added. According to electrostatic theory the curvature ($d^2\phi/dx^2$) of the potential is proportional to the local electric charge density $\rho(x)$. Measurements for highly anisotropic systems such as n-octanol containing sodium dodecyl sulfate exhibit some interesting effects which will be compared with results for simpler mixtures.

NUMERICAL STUDY OF BUOYANCY EFFECTS ON LAMINAR DIFFUSION FLAMES.

Paul V. Hyer, Lockheed Corp., Hampton, VA 23666, Dennis Stocker*, NASA Lewis Research Center, Cleveland, OH 44135 & Ivan O. Clark*, NASA Langley Research Center, Hampton, VA 23665.

A numerical modeling experiment has been conducted to study the influence of gravitational acceleration on the aerodynamics and chemistry of a laminar diffusion flame. The results have been compared with experiments conducted in drop towers at the NASA Lewis Research Center, in which hydrocarbon flames were observed photographically during free-fall. The experimental apparatus consisted of a circular cylindrical chamber supplied at one end with an axial source of methane fuel surrounded by a coflowing mixture of nitrogen and oxygen. The model assumed cylindrical geometry with azimuthal symmetry and used a global reaction scheme featuring seven chemical species and six reactions. Research cases included the drop-tower configuration with gravity levels set to normal Earth gravity, milli-gravity or zero gravity. Calculated distributions of chemical species were compared with published results from the literature.

CHARACTERIZATION OF X-RAY ELASTIC CONSTANTS IN A Ti-14Al-21Nb/SiC METAL MATRIX COMPOSITE. J. Jo, R.W. Hendricks, Materials Engineering, Dept., Va. Polytechnic Inst. and State Univ., Blacksburg, Va 24061, & W.D. Brewer*, K.M. Brown*, Metallic Materials Branch, NASA Langley Res. Ctr, Hampton, Va 23665. The x-ray elastic constant is a conversion factor required for the determination of residual and loading stresses by diffraction techniques. Plots of d-spacing versus $\sin^2\psi$ of the {843} family of crystallographic planes in a Ti-14Al-21Nb/SiC metal matrix composite were obtained at different stress levels using an MTS testing machine and an x-ray stress analyzer. The required elastic constant was determined from the slopes of these plots and the corresponding stresses. The extrapolation of these data to zero applied stress provides the residual stress in the unloaded material. In order to investigate the variation of the residual stresses in the metal as a function of depth below the sample surface, the sample was electropolished in steps of approximately 6 microns down to the first fiber layer. After each electropolishing, the residual stress and the x-ray constant were re-determined. The causes for the stresses will be discussed in terms of the differences in the coefficient of thermal expansion of the fibers and the metal matrix, while the spatial variation of the elastic constants will be discussed in terms of various models for the bonding between the fibers and the matrix. (Research supported by the NASA Langley Res. Ctr.)

CREVICE CORROSION OF ALLOY 625 IN SEAWATER. M. P. Jurinski & J. R. Scully, Dept. of Materials Science, Univ. of VA, Charlottesville, VA 22903. Alloy 625 is a Ni-Cr-Mo alloy with generally excellent resistance to all forms of corrosion in seawater. The corrosion resistance is due to the formation of a passive film on the alloy surface. However, Alloy 625 has been found to be susceptible to crevice corrosion when exposed to certain solution chemistries. These chemistries are the result of an occluded cell created at the metal surface. Increased concentrations of chemical species within the occluded cell are thought to be responsible for the degradation of the passive film resulting in anodic dissolution of the material. Alloy 625 has been designated as a possible replacement for cupro-nickel alloys in seawater piping systems of future naval vessels. Since tight crevices are an inherent component of flanges and other piping connections, this study is being conducted to define the regimes of susceptibility and immunity for alloy 625. (Funded by Newport News Shipbuilding)

ELECTROCHEMICAL MEASUREMENTS FOR THE VISUALIZATION OF CONVECTION IN LIQUID METAL. Ker-Yih Kao, & T. J. Anderson, & R. Narayanan, Dept. of Chem. Engr., Univ. of Fl., Gainesville, FL 32611, & A. L. Fripp, NASA, Langley Res. Ctr., M.S. 473, Hampton, VA 23665. An electrochemical technique for the visualization of natural convection in liquid metals and semiconductors in the vertical Bridgman melt-growth configuration is developed and tested. Electrochemical cells that employ the ceramic solid electrolyte yttria-stabilized zirconia as the boundaries of the fluid container are used to titrate and measure oxygen tracer in the liquid metal. Preliminary measurements of the diffusivity of oxygen in liquid tin have been made. The measurements are in good agreement with other researchers' results. An experimental cell designed to measure the effective diffusivity of oxygen in liquid tin should be able to discern transcritical points in the dynamic state of the melt as a function of imposed temperature gradient. The electrochemical technique will be modified to show the orientation of convection flow in the Bridgman simulation. (Supported by NASA Grant NAG-1-609)

AN ANNEALING STUDY OF STRAIN RELAXATION IN InGaAs/GaAs HETEROSTRUCTURE J. Kui and W.A. Jesser, Dept. of Materials Science, Univ. of Va. Charlottesville, Va. 22903. Epitaxial layers of InGaAs were grown on GaAs substrates at atmospheric pressure in such a way that a thickness gradient was realized. Anneals were performed just after growth at different times and temperatures. Strain relaxation during the growth was studied by optical microscopy and transmission electron microscopy. These experiments show that misfit strain can be relaxed by generation of misfit dislocations by means of a kinetic process. The kinetic constant has a linear relationship with excess thickness ($h-h_0$) and also is a function of number of threading dislocations of the substrates and the annealing temperature. The activation energy of the relaxation process also can be calculated from the experimental data. After long annealing time, the sample reaches its steady state in which a residual strain apparently still exists which is not accommodated by misfit dislocations. These experimental results are in good agreement with the kinetic model of misfit dislocations generation developed by Fox and Jesser.

A TEM CHARACTERIZATION OF COBALT-ZIRCONIUM ALLOYS. Kenneth R. Lawless, Dept. of Materials Science, University of Virginia, Charlottesville, VA 22903. Considerable interest has been shown in the hard magnetic properties of Co-Zr, Co-Zr-B, and Co-Hf-B alloys. This study reports preliminary microstructural studies on the Co-Zr binary alloys with compositions near $\text{Co}_{11}\text{Zr}_2$. Melt spun samples were heat treated at temperatures around 900° C. All samples were found to be microcrystalline and multiphase in character. The major phase present in all cases was a heavily faulted phase with composition near $\text{Co}_{11}\text{Zr}_2$ or Co_7Zr_2 . Also present in lesser amounts were twinned FCC cobalt and a near perfect cubic phase $\text{Co}_{23}\text{Zr}_6$. Moderately high resolution images and diffraction patterns will show the structure of these phases.

FRACTURE OF ADVANCED ALUMINUM ALLOYS AT ELEVATED TEMPERATURES. William C. Porr, Jr., Yang Leng, and Richard P. Gangloff, Dept. of Matls. Sci. and Eng., Univ. of Va., Charlottesville, Va. 22903. The unusual intrinsic ductility decrease with increasing temperature associated with advanced rapidly solidified powder metallurgy (RS/PM) aluminum alloys is discussed, with emphasis on alloy 8009. 8009 is a rapidly solidified Al-8.5Fe-1.3V-1.7Si (wt.%) alloy manufactured by Allied-Signal, Inc. that exhibits exceptional strength retention with long term elevated temperature exposure due to the thermal stability of the strengthening $\text{Al}_{12}(\text{Fe}, \text{V})_3\text{Si}$ dispersoid. With increasing temperature, alloy 8009 exhibits a decrease in tensile ductility and fracture toughness with no apparent associated change in microscopic fracture mode. A loading rate dependence of ductility and fracture toughness at elevated temperatures is also observed, implying a time-temperature dependent mechanism for the evolution of deformation and fracture in this alloy. Evidence is presented discounting any role of environmental embrittlement in this elevated temperature behavior. Solute-dislocation interactions (strain aging) and/or novel deformation micromechanisms are hypothesized to account for the decrease in ductility and fracture toughness at elevated temperatures observed in the advanced RS/PM aluminum alloys. (This research was supported by the NASA-Langley Research Center, Grant NAG-1-745. Material was donated by Allied-Signal, Inc.)

MECHANICAL AND THERMAL PROPERTIES OF CERAMIC AND METAL PARTICULATE REINFORCED HIGH TEMPERATURE POLYMERS. D. C. Raqué and R. G. Kander, Mat. Eng. Dept., VPI&SU, Blacksburg, Va. 24061-0237. As the upper use temperature of high performance polymers continues to climb, it is important to characterize the properties of composites formed from these resins. Of specific interest in structural and semi-structural applications are composites formed from reinforcements which are also stable at high temperature (e.g., metals and ceramics). In this study, the effect of reinforcing high-temperature polymers with ceramic and metal particles is evaluated. Ceramic reinforcements include mica powder and NICALON™ chopped fibers, while metal reinforcements include fine copper and copper-aluminum-nickel alloy powders. Polymers studied include polyimide thermoplastic powders and high-temperature epoxy thermosetting resins. Mechanical properties investigated include strength, modulus, and toughness. The high temperature stability of these properties is also investigated. Thermal properties studied include thermal expansion, glass transition temperature, and heat capacity.

INVESTIGATION OF SURFACE ENERGIES OF SOLIDS BY MEANS OF CORRELATION PLOTS INVOLVING CONTACT ANGLE MEASUREMENTS. G. A. Reitz and R. E. Barker, Jr., Dept. of Mater. Sci., University of Va., Charlottesville, Va. 22903. A method of determining contact angles (θ) from the relative dimensions of height to chord ratios for small drops is presented. The result is $\cos \theta = [1 - 4(h/c)^2] / [1 + 4(h/c)^2]$. A technique is developed in which the collective data of critical surface tensions (γ_c) and θ for a number of similar solids with a single liquid are used to predict γ_c for a solid whose critical surface tension is unknown, from a single contact angle measurement with the chosen liquid. Examples of the correlation achieved for some polymer/liquid systems are presented, and possible causes for deviation from predicted ideal behavior are discussed. The method of contact angle measurements has proved useful in investigating the effects of photochemical modifications of polymer surfaces by ultraviolet radiation.

DEGRADATION MODES IN TYPE R THERMOCOUPLES. William R. Rosch, Dept. of Mat. Sci. UVA, William J. Debnam & Archibald L. Fripp, NASA Langley Research Center. Thermocouples are the most common tool for measuring temperatures. Type R thermocouples made from platinum and rhodium are workhorses for accurate temperature measurements from 800-1600°C. Work will be presented that shows that bare wire TC's and TC's covered with a protective sheath can be contaminated and degraded by exposure to other metals at high temperatures. Results of tests will show that the amount of damage depends on the time of exposure and the exposure temperatures.

EVALUATION OF THE ELECTROCHEMICAL IMPEDANCE RESPONSE OF ALUMINUM IN SODIUM BORATE BUFFER ELECTROLYTE. Gayle R. T. Schueller and S. Ray Taylor, *Materials Science Department, University of Virginia, Charlottesville, VA 22903.* Electrochemical impedance studies were conducted on aluminum samples exposed to borate buffer electrolyte in order to confirm an equivalent circuit model for this system based on physical parameters such as oxide thickness and dielectric constant. A variety of aluminum alloys were tested with particular emphasis on high purity (99.999%) aluminum. The electrolyte, consisting of 0.1M sodium borate buffered with boric acid to pH 7 was chosen to minimize pitting, thereby simplifying the overall impedance response of the system. This impedance response was modeled by a parallel combination of oxide resistance and capacitance, in series with a solution resistance. It was found that experimental capacitance values were inversely proportional to anodized oxide thicknesses as predicted by parallel-plate capacitor equations and that capacitance increased with time in solution. Since XPS analysis of the oxide thickness of air-formed oxides before and after exposure to borate buffer indicated no statistically significant change in oxide thickness as a function of exposure time, the increased capacitance was attributed to an increase in the dielectric constant due to hydration.

DISCOVERY AND IDENTIFICATION OF THE 'CUBIC PHASE' IN REINFORCED Al-Cu-Mg ALLOYS. Randy D. Schueller, F.E. Wawner, and A.K. Sachdev*, *Materials Science Dept., Univ. of Virginia, Charlottesville, VA 22901.* An Al-4Cu-2Mg alloy reinforced with 20 volume percent SiC whiskers was examined after a T7 heat treatment. The expected precipitate phase was equilibrium S' (Al₂CuMg), as was confirmed in an unreinforced heat treated alloy. When reinforcement was added to this alloy, however, other precipitate phases formed in addition to S'. These included plate shaped θ' (Al₂Cu) and an interesting cubic shaped phase with edge lengths of 300-500Å. The atomic structure of this phase was determined to be cubic with a lattice parameter of 8.33Å which made it semi-coherent with the {001} Al planes. The cubic phase was identified as Al₅Cu₈Mg₂ and was determined to be a metastable phase which nucleated and grew during the warm water quench following solution treatment. The high concentration of these phases along with their physical properties suggests they have great potential for precipitate strengthening at intermediate and high temperatures.

THE ROLE OF RESIDUAL AND APPLIED STRESSES IN HYBRID THICK FILM CIRCUITS. N.N. Schulz, A. Elshabini-Riad*, The Bradley Dept. of Electrical Engineering & M.T. Stawovy*, J. Jo, K.L. Venzant*, D. Vijay*, R.W. Hendricks, *Dept. of Materials Engineering, Va. Polytechnic Inst. & State Univ., Blacksburg, Va. 24061.* We have investigated the role of residual and applied stresses on the mechanical integrity and electrical performance of thick film hybrid microelectronic circuits. Because of the significant difference in the linear coefficient of thermal expansion between the alumina substrate and the Ag-Pd metallization, there are significant tensile stresses in both the metallization and on the back (non-component) side of the substrate. It has been determined that circuit manufacturing causes residual stresses that are as large as 50% of the modulus of rupture of the material. Furthermore, it has been found that these residual stresses as well as applied loads have a significant effect on the high-frequency (10 GHz) electrical response of the metallization. We will discuss the results of our studies using x-ray diffraction and strain gages to determine the stresses. We will also describe the calibration of the relationship between stresses and electrical performance of simple circuits through the use of time domain reflectometry measurements in a calibrated cantilevered beam.

GAMMA-RAY AND X-RAY IMAGING STUDIES OF THE LOCATION AND SHAPE OF THE MELT-SOLID INTERFACE IN THE BRIDGMAN GROWTH OF LEAD-TIN TELLURIDE AND GERMANIUM. R. T. Simchick, S. Sorokach, Lockheed Engineering and Sciences Co., Hampton, VA, USA; A. L. Fripp, W. Debnam, R. F. Berry, NASA Langley Research Center, Hampton, VA, USA; and P. G. Barber, Longwood College, Farmville, VA, USA. The melt-solid interface is an important parameter in Bridgman crystal growth. Interface shape and position are important processing variables that are controlled by a combination of material properties and furnace controls. Therefore, the ability to visualize the interface in real time during crystal growth from furnaces is a valuable tool. Procedures have been developed to observe the shape and movement of the melt-solid interface during Bridgman growth of lead-tin telluride and germanium. This was accomplished by combining x-ray and gamma ray image intensified images with modified procedures for image enhancement. The techniques developed have general applicability to other crystal growth techniques. This presentation will discuss the technique used to produce real-time interface images; followed by a presentation of a few images illustrating image enhancement techniques; and finally, images showing the interface throughout the growth of the semiconductor crystals.

MICROSTRUCTURAL CHARACTERIZATION OF SILICON-GERMANIUM-GALLIUM PHOSPHIDE ALLOYS. V. Srikant & W. A. Jesser, Dept. of Mat. Sci., Univ. of Va., Charlottesville, Va 22903. Two different alloys of silicon-germanium were investigated in order to investigate the effects of GaP additions to these alloys. 10 - 15 at % GaP was added to these alloys. It was found that the maximum solubility of GaP in 50/50 Si-Ge was about 6 at% and that in 80/20 Si-Ge was about 7.8 at%. It was also found that GaP forms a low melting eutectic with these alloys. The shape and orientation of these eutectic structures depended on the rate at which they were cooled down to room temperature. On rapid cooling from temperatures above the eutectic temperatures lamellar structures oriented along [100] directions were observed. As the cooling rate was decreased these eutectic structures lost their lamellar shape. It was also found that the matrix around the eutectic became richer in germanium with decreasing cooling rate. Further it was determined that the eutectic temperature of the 80/20 Si-Ge alloy lies between 1125° C and 1150° C.

XPert: An expert system for the validation and interpretation of X-Ray residual stress data. Marc Tricard, Scott Courtney, Robert Hendricks. Materials Engineering Dept, VA Tech, Blacksburg, VA, 24061. Although widely recognized in the research community as one of the most accurate non-destructive methods for the determination of residual stress in polycrystalline structural materials, X-ray diffraction has not been extensively adopted in the field. We believe that computer assistance could contribute to the promotion of this technique by increasing the productivity and accuracy of these measurements. We have developed a prototype of an expert system, using Nexpert Object's shell, to assist a non-trained operator in the validation and interpretation of X-ray diffraction residual stress data. Its knowledge base contains relevant examples of the rules necessary for data validation. The prototype has also validated most of the concepts required for the implementation of a full scale version by evaluating all of the major technical features such as graphic representation, external routine calls, and databases accesses.

THERMO-ACOUSTIC MONITORING OF DAMAGE ACCUMULATION IN POLYMERS AND POLYMER-BASED COMPOSITES. R. K. Verma and R. G. Kander, Mat. Eng. Dept., VPI&SU, Blacksburg, Va. 24061-0237. A damaged polymer or composite sample contains "damage areas" (microcracks, delaminations, etc.) which are typically in a state of residual stress. The internal surfaces of these damage areas would prefer to slide past one another due to this anisotropic internal stress state. However, mechanical interlocking of the surfaces hinders this sliding movement. When such a damaged sample is gently heated ($\leq 100^\circ\text{C}$), some of the mechanical interlocking is relaxed, and the surfaces slide past one another releasing stored elastic energy in the form of acoustic waves. Local anisotropy in the coefficient of thermal expansion leads to similar sliding movement, generating additional acoustic waves. Literature results have shown that these "thermo-acoustic emissions" can be monitored to study the extent and type of damage which exists in a polymer or composite sample. In this work, thermo-acoustic emission monitoring is developed as a quantitative tool for the non-destructive study of the damage accumulation process in polymers and composite materials. Correlations are developed between the amount and type of prior damage and the thermo-acoustic emissions produced.

THE SYNTHESIS, MICROSTRUCTURE, AND THERMAL PROPERTIES OF $(\text{Ca},\text{Mg})\text{Zr}_4(\text{PO}_4)_6$ CERAMICS. Y. Yang, T. K. Li*, D. A. Hirschfeld, and J. J. Brown*, Center for Advanced Ceramic Materials, Virginia Polytechnic Institute and State University, Blacksburg, Va. 24061-0256. $(\text{Ca}_{0.6}, \text{Mg}_{0.4})\text{Zr}_4(\text{PO}_4)_6$ ceramics were synthesized by sol-gel and solid state reaction techniques. For the sol-gel derived compositions sintered within the temperature range of 1150 to 1300°C , the bulk thermal expansion coefficient varied from $3.02 \times 10^{-6}/^\circ\text{C}$ to $-2.18 \times 10^{-6}/^\circ\text{C}$ depending on the heat treatment conditions. A similar variation in the bulk thermal expansion was found for the ceramics formed using a solid state reaction technique, but the range was limited to $0.8 \times 10^{-6}/^\circ\text{C}$ to $0.9 \times 10^{-6}/^\circ\text{C}$. The observed variation in thermal expansion was related to the microstructure of the ceramic.

Medical Sciences

ROLE OF CALCIUM IN ISCHEMIA-REPERFUSION INJURY OF THE CARDIAC SARCOPLASMIC RETICULUM. Alaa E. Abdelmequid, Dept. of Cardiology, Med. Col. of Va., Richmond, Va. 23298, & Joseph J. Feher*, Dept. of Physiology, Med. Col. of Va., Richmond, Va. 23298. We examined the role of perfusate $[\text{Ca}]$ in the function of the cardiac sarcoplasmic reticulum (CSR) in ischemia in a Langendorff rat heart model with 5 rats per group. All hearts were perfused for 20 min with Krebs buffer containing 1.4 mM Ca . Hearts in group I were perfused for an additional 15 min with this same solution. Hearts in group II were perfused for an additional 5 min with the 1.4 mM Ca and then were exposed to 10 min of global normothermic ischemia. Hearts in group III were perfused with 0.2 mM Ca for 5 min prior to 10 min of ischemia. The CSR function was assessed by measuring the Ca uptake rate of ventricular homogenates, expressed as $\text{nmol/min-mg protein}$, under two conditions: (a) with $500 \mu\text{M}$ ryanodine (RY); (b) with no RY. This concentration of RY has been shown to close the CSR Ca release channel. With 1.4 mM Ca perfusion, ischemia reduced CSR function 40% when measured with no RY (18.5 in group I compared to 10.9 in group II). This decrease was not observed when 0.2 mM Ca was perfused prior to ischemia (17.8 in group III). This protective effect of low Ca perfusion on CSR function was not observed when CSR function was measured with RY (32.6 in group II and 32.6 in group III) to close the Ca efflux pathway. These results suggest that extracellular Ca is involved in the ischemic damage to CSR by effects on the ryanodine-sensitive Ca release channel of the CSR. Perfusion with low Ca prior to ischemia prevents the persistent inappropriate opening of the release channel. (Supported by a grant from the American Heart Association, Va. Affiliate, Inc.)

ROLE OF CALCIUM IN THE LONG TERM REGULATION OF THE CALCIUM-RELEASE CHANNEL OF THE CARDIAC SARCOPLASMIC RETICULUM. Alaa E. Abdelmeguid, Dept. of Cardiology, Med. Col. of Va., Richmond, Va. 23298, & Joseph J. Feher*, Dept. of Physiology, Med. Col. of Va., Richmond, Va. 23298. We examined the role of Ca in the function of cardiac sarcoplasmic reticulum (CSR) by perfusing Langendorff-mounted rat hearts with solutions of varying [Ca]. After 20 min perfusion with Krebs solution containing 1.4 mM Ca, the hearts were perfused for an additional 5 min with Krebs solution containing (a) 0.2 mM Ca, group I, n=8; (b) 1.4 mM Ca, group II, n=8; (c) 2.8 mM Ca, group III, n=8; (d) 5.6 mM Ca, group IV, n=8. The CSR function was then evaluated by measuring the Ca uptake rate of ventricular homogenates (expressed as nmol Ca taken up per min per mg protein) under two conditions: (a) with 500 μ M ryanodine (RY); and (b) with no RY. The CSR function measured in the absence of RY decreased systematically with increasing perfusate [Ca] (25.7, 21.4, 17.2, and 16.3 in groups I, II, III, and IV, respectively). However, CSR function was not affected by perfusate [Ca] when the Ca release channel was blocked by RY (44.5, 46.0, 48.0, 45.6, groups I, II, III, and IV, respectively). These results point to an important role of Ca in the long-term regulation of CSR function by acting on the ryanodine-sensitive Ca release channel. This action probably involves a conformational change that can last for at least several minutes. This regulation is probably different from the beat-to-beat regulation of the CSR by Ca (Ca-induced Ca release). The channel represents a potential site at which high cytosolic [Ca] could cause a persistent opening of the CSR Ca release channel, leading to a further loss of cellular Ca homeostasis and subsequent further damage. (Supported by a grant from the American Heart Association, Va. Affiliate, Inc.)

CONTRIBUTIONS OF TUMOR NECROSIS FACTOR- α IN TUMOR-INDUCED IMMUNOSUPPRESSION. D.G. Allewa and K.D. Elgert. Dept. of Biology, Microbiology & Immunology Section, Va. Polytechnic Inst. & State Univ., Blacksburg, VA 24061. By increased production of suppressive molecules such as prostaglandin E₂ (PGE₂), macrophages (M ϕ) from tumor-bearing hosts (TBH) show greater suppression of alloreactivity than normal host (NH) M ϕ . Tumor necrosis factor- α (TNF- α), a tumoricidal monokine produced by M ϕ during tumor growth, can regulate M ϕ PGE₂ production. We assessed the contribution of TNF- α to tumor-induced M ϕ -mediated suppression of CD4+ T cell allorecognition by adding TNF- α , anti-TNF- α antibodies, and/or indomethacin, a blocker of PGE₂ production, to murine mixed lymphocyte reaction (MLR) cultures in the presence or absence of NH or TBH M ϕ . TNF- α increased alloreactivity in the absence of M ϕ but decreased it when NH or TBH M ϕ were added. Anti-TNF- α antibodies had little effect on T cell allorecognition in the absence of M ϕ but increased alloreactivity in the presence of TBH M ϕ to a greater extent than in the presence of NH M ϕ . Indomethacin treatment partly restored reactivity in M ϕ and TNF- α -added MLR cultures but the restoration was significantly increased in the presence of TBH M ϕ . These results suggest that TBH M ϕ can be more suppressive than NH M ϕ by producing more TNF- α and/or being more susceptible to PGE₂ production induced by TNF- α .

EXPRESSION OF DEVELOPMENTALLY REGULATED GENES IN MACROPHAGES DURING TUMOR GROWTH. D. Askeu and K.D. Elgert. Dept. of Biology, Microbiology & Immunology Section, Va Polytechnic Inst. & State Univ., Blacksburg, VA 24061. Macrophages (M ϕ) play an important role in tumor-induced immunosuppression. We previously have characterized changes in M ϕ function and phenotype during tumor growth. Of interest was the discovery of an increase in immature M ϕ in tumor-bearing hosts (TBH). Mac-2, a surface marker found on mature elicited M ϕ , is considered to be developmentally regulated. Flow cytometric analyses showed a decrease of Mac-2+ M ϕ during tumor growth, which supported our earlier work. Mac-2 has lectin-like properties and has been reported to be an IgE-binding protein. Mac-2 is found in cytoplasmic and membrane fractions but lacks a transmembrane domain. Western blot analyses of TBH thioglycollate-elicited peritoneal M ϕ showed a decrease in both cytoplasmic and membrane forms. Northern blot analyses of TBH M ϕ showed a decrease in Mac-2 mRNA, which suggested that tumor growth suppresses the expression of Mac-2 mRNA and the subsequent expression of the cytoplasmic and membrane forms of the protein. The decrease in Mac-2 mRNA expression signals a shift from a population of mature M ϕ to a population of immunosuppressive immature M ϕ . (Supported by Sigma Xi and VAS Grants)

EFFECT OF MULTIVITAMINS ON SERUM VITAMIN A AND E LEVELS IN DIALYSIS PATIENTS. R.B. Brandt, W.G. Gutheim, B. Dezzutti, Dept. of Biochemistry, MCV/VCU, Richmond, VA 23298, D.A. Sica, T.W. Gehr, Dept. of Med., Div. of Nephrology, MCV/VCU & J.M. Hain, Dept. of Gen. Surgery, St. Joseph Mercy Hosp., Ann Arbor, Michigan. Serum retinyl palmitate (RP) levels closely correlate with toxicity of hypervitaminosis A. The dialysis patients studied received a two-month course of nephrocaps followed by a two-month course of a daily oral multivitamin containing 5000 IU vitamin A and 10 IU vitamin E. Nephrocaps lack vitamins A, and E. There was no statistical difference between baseline and nephrocaps-treated patient serum retinol (ROH) and RP levels, but there was an elevation for patients on multivitamins in ROH. The serum ROH levels were $110 (\pm 37) \mu\text{g/dL}$ (mean \pm SD) (N=23) for baseline (normal 30-70 $\mu\text{g/dL}$), $116 (\pm 26)$ (N=12) on nephrocaps, and $141 (\pm 21)$ (N=7) on multivitamins. The serum RP levels were below 10 $\mu\text{g/dL}$, while hypervitaminosis patients usually exceed 50 $\mu\text{g/dL}$. Vitamin E levels in patients were not affected by supplementation of daily oral multivitamin. (Supported in part by funds from the Smokeless Tobacco Research Council, Inc.)

ATTEMPTS TO DEVELOP 5-HT_{1C}-SELECTIVE PHENALKYLAMINES. P. Bartyzel^{*}, R. Raghupathi, M. Teitler, R. A. Glennon, Dept. of Medicinal Chemistry, MCV/VCU, Richmond, VA 23298. 5-HT_{1C} serotonergic receptors closely resemble 5-HT₂ receptors in terms of molecular biology and pharmacology; there are no ligands currently available that show appreciable selectivity for one set of receptors over the other. Earlier studies in our laboratory have shown that phenalkylamines such as DOM, DOB and DOI bind with reasonably high affinity at both 5-HT_{1C} and 5-HT₂ receptors. Systematic modifications were introduced in the phenalkylamine nucleus which, from preliminary data, appeared to decrease 5-HT₂ but not 5-HT_{1C} affinity, in order to develop analogues with improved 5-HT_{1C} selectivity. In addition, these studies were expected to yield structure-affinity relationship (SAFIR) data at 5-HT_{1C} receptors, which are essentially non-existent. Although the highest 5-HT_{1C}/5-HT₂ selectivity obtained was only 14-fold, useful indications were obtained for improvement of 5-HT_{1C} affinity and selectivity (for instance, removal of the α -methyl or the 5-methoxy substituent results in improved selectivity for 5-HT_{1C} over 5-HT₂ receptors). Using these indications, it should be possible to design compounds with enhanced 5-HT_{1C} affinity and selectivity.

In vitro characterization of a cannabinoid receptor using the synthetic analogs (-)-11-OH- Δ^9 -THC-DMH and CP-55,940. D. Troy Bridgen, Xin Wei, David R. Compton, and Billy R. Martin, Dept. of Pharmacology and Toxicology, MCV/VCU, Richmond, VA, 23298. The dimethylheptyl (DMH) analog of 11-OH- Δ^9 -tetrahydrocannabinol (THC) possesses a long branched side chain, rather than the normal pentyl side chain of Δ^9 -THC. However, 11-OH- Δ^9 -THC-DMH more closely resembles naturally occurring cannabinoids than the bicyclic compound CP-55,940 which has been used by others to radiolabel a cannabinoid binding site. Radioligand binding assays were established using both compounds, and the characteristics of the assays compared by equilibrium, thermodynamic, and displacement analyses. 11-OH- Δ^9 -THC-DMH possessed a K_D of 1.2 ± 0.1 nM (mean \pm S.E.) and a B_{max} of 2.8 ± 0.3 pmol/mg protein. CP-55,940 possessed a K_D of 0.72 ± 0.08 nM and a B_{max} of 2.5 ± 0.8 pmol/mg protein. Rank ordering of five compounds according to potency for displacing ³H-CP-55,940 accurately indicated the potency of these compounds for their ability to also displace ³H-11-OH- Δ^9 -THC-DMH. The binding of either ligand at 30 °C was favorable ($\Delta G = -98$ and -107 kcal/mol for 11-OH- Δ^9 -THC-DMH and CP-55,940 respectively), and driven by entropic forces ($\Delta S = 369$ and 152 cal/°K-mol, respectively) rather than enthalpic forces ($\Delta H = 13.7$ and 9.7 kcal/mol, respectively). Thus, both ligands appear to label identical binding sites in a similar fashion. (Supported by NIDA grant DA-03672 and a Pharmaceutical Manufacturers Assoc. Foundation Award #90-0133.)

MEASURING LOW LEVEL CROCIDOLITE: A COMPARISON OF MICROSCOPIC METHODS USED IN THE ANALYSIS OF AIRBORNE ASBESTOS. Michael T. Chermak, Douglas J. Anderson, William E. Keefe, Robert E. Tompkins & R. Leonard Vance, Dept. of Prev. Med., Med. Col. of Va., Richmond, Va. 23298. Asbestos exposure may cause ill-health effects primarily to the respiratory system. Many believe that mesothelioma may result from low level crocidolite exposure. The objective of this study is to determine whether phase contrast microscopy (PCM) is adequate to detect airborne crocidolite. Transmission electron microscopy (TEM) will be used to ensure that airborne crocidolite fibers invisible to PCM are not present in selected offices of West Hospital at the Medical College of Va. Crocidolite is 90% of a highly friable sprayed-on asbestos insulation material located above the dropped ceiling in these offices. Patently, exposure levels will vary accordingly with activity. However, this study concludes PCM & TEM detect no substantial levels (≈ 0.005 f/cc, TEM) of airborne asbestos.

EFFECTS OF COOLING ON ALPHA ADRENERGIC RECEPTORS OF ISOLATED RAT BLOOD VESSELS. William Covell* and J.L. Hart. Biol. Dept., George Mason Univ., Fairfax, VA 22030

The thoracic aorta and femoral vein were isolated from Sprague Dawley rats to investigate the effects of cooling on alpha adrenergic receptors. Vessel rings were suspended in Krebs solution in jacketed tissue baths for the recording of isometric tension. The vessels were exposed to cumulative concentrations of alpha-1 (phenylephrine) or alpha-2 (oxymetazolin) agonists at 37°C and at 24°C. Vessels responded to both alpha agonists with concentration-related increases in tension. Alpha-1 responses of both vessels were depressed by cooling. However, alpha-2 contractions of the vein were significantly increased by cooling while those of the thoracic aorta were decreased. These differences in the alpha-2 responses to cooling of the superficial vein and deep artery are consistent with the suggestion that alpha-2 adrenergic receptors play a role in the redistribution of blood flow away from superficial areas of the body during thermoregulatory adjustments of the circulation.

SINGLE OR CHRONIC DOI ADMINISTRATION INDUCES SUPERSENSITIVITY TO 5-HT₂ RECEPTOR FUNCTION: BEHAVIORAL AND BINDING STUDIES. N. A. Darmani, B.R. Martin, K. Miller, M. Teitler and R.A. Glennon. Depts. Pharmacol./Toxicol, Med. Chem. MCV/VCU, Richmond, VA. Both 5-HT₂ selective agonists and antagonists reduce head-twitch response (HTR) upon chronic administration. The purpose of the present study was to examine agonist-induced attenuation. A single DOI injection (2.5 mg/kg, i.p.) produced 40 ± 1 HTRs in 20 min. A second injection administered either 24, 48, 144 or 192 h following the first produced 23 ± 1 ($p < 0.05$), 56 ± 3 ($p < 0.05$), 53 ± 2 ($p < 0.05$) and 35 ± 2 ($p > 0.05$) HTRs respectively. When mice were injected with DOI once daily for 13 days, a significant reduction in HTR frequency (41-21%) occurred on days 2 to 6. Thereafter, the HTR number slowly returned to control. When mice were challenged with DOI either 48, 96, 144 or 240 h following cessation of chronic treatment, the respective HTR scores were: 57 ± 2 ($p < 0.05$), 46 ± 1 ($p < 0.05$), 42 ± 1 ($p < 0.05$) and 36 ± 3 ($p > 0.05$). Acute DOI administration had no effect whereas chronic administration reduced the 5-HT₂ receptor capacity by 40%. Thus, acute and chronic DOI administration can induce a supersensitive effect which appears 48h following last injection and can persist for the next 144 h. Such a supersensitive state in the presence of reduced 5-HT₂ receptors suggest a change in the sensitivity of its transduction mechanism. (NIDA grants DA-02396 and DA-01642).

5-HT₂ SEROTONIN BINDING PROPERTIES OF N-SUBSTITUTED PHENYLALKYLAMINES AND TRYPTAMINES. J. De Los Angeles, M. Teitler, and R.A. Glennon, Dept. of Medicinal Chemistry MCV/VCU Richmond, VA 23298. 1-(4-Bromo-2,5-dimethoxyphenyl)-2-aminopropane (DOB) and 5-methoxy- α -methyltryptamine (5-MeO- α -MeT) are representative of two major classes of 5-HT₂ agonists. DOB and 5-MeO- α -MeT bind with high affinity (K_i = 0.79 and 7 nM, respectively) to the agonist high affinity state (5-HT_{2H}) of 5-HT₂ receptors labeled by [³H]DOB, but bind with significantly lower affinity to the low affinity state (5-HT_{2L}) labeled by [³H]ketanserin. 5-HT₂ antagonists such as ketanserin bind with equal affinity to both states. Thus, structure affinity relationships (SAFIR) of 5-HT₂ agonists obtained using [³H]DOB as the radioligand may be more accurate; therefore, it is necessary to re-examine the SAFIR of 5-HT₂ agonists at 5-HT_{2H} sites. Prior SAFIR studies of the two classes indicate that substitution with small alkyl groups on the terminal amine to yield secondary and tertiary amines results in minor to drastic reduction in binding affinity, depending on the size of the substituents and degree of substitution. However, relatively little is known about the influence of N-monosubstitution utilizing larger substituents. The α -methyl group does little to enhance or reduce affinity. Hence, a series of α -desmethyl DOB and 5-methoxytryptamine derivatives monosubstituted at the terminal amine with small alkyl to large aralkyl groups were synthesized and their 5-HT_{2H} binding affinity was evaluated. Surprisingly, most analogs in both classes retain high affinity even with the larger aralkyl groups. In fact, the N-benzyl derivatives are equipotent with, if not more potent, than the unsubstituted parent compounds.

Pharmacological Evaluation of Nicotine and Mecamylamine Analogs. Katherine R. Dimen, Everett L. May and Billy R. Martin, Dept. of Pharmacol. and Toxicol., MCV/VCU, Richmond, VA 23298. To investigate the mechanism of mecamylamines' antagonism of nicotine in the CNS, the dose-response curves for depression of antinociception and depression of spontaneous activity by nicotine were recorded in the presence of increasing concentrations of mecamylamine analogs. Nicotine produced a dose responsive depression of antinociception and depression of spontaneous activity with ED₅₀'s of 2.9 and 0.8 mg/kg, respectively. The (\pm)-exo-isomer of mecamylamine antagonized the effect of nicotine at these ED₅₀ doses with AD₅₀'s of 0.27 mg/kg for antinociception and 0.08 mg/kg for spontaneous activity. Antinociceptive testing revealed that compounds 7 and 15 were the most effective antagonists of nicotine with AD₅₀'s of 0.3 and 0.6 mg/kg, respectively. Compounds 1, 3, 5 and 6 produced moderate antagonism of nicotine, with AD₅₀'s of 1.7, 1.4, 1.2 and 2.8 mg/kg, respectively. Nicotine-induced spontaneous activity was antagonized most effectively by compounds 3 and 7, with AD₅₀'s of 0.9 and 0.7 mg/kg, respectively. Compound 6 antagonized nicotine with an AD₅₀ of 2.3 mg/kg. Compound 1 produced 29% antagonism at a 10 mg/kg dose, and compound 15 had an AD₅₀ of 12.3 mg/kg. These results indicate that one methyl group on the nitrogen gave the highest antagonistic activity in the tail flick and spontaneous activity evaluations. Increasing the length (straight chain or branched) of the N-alkyl substituent decreased antagonist activity. Also, specificity for tail flick antagonism was produced by a di-alkyl substituent at the nitrogen.

INTRATHECALLY- ADMINISTERED CALCITONIN GENE-RELATED PEPTIDE PRODUCES DOSE-DEPENDENT HYPOTHERMIA IN MICE. Dombrowski D. S., Smith F. L., Welch S. P., and Dewey W. L., Dept. of Pharm./Tox., Med. Col. of Va., Va. Commonwealth Univ., Richmond, Va. 23298. The ratio of calcium to sodium ion concentrations in the cells of the posterior hypothalamus is the major determinant of body temperature set-point. When the intracellular calcium to sodium concentration ratio rises, the body temperature set-point decreases resulting in hypothermia. When the intracellular sodium to calcium concentration ratio rises, the body temperature set-point increases, resulting in hyperthermia (sodium fever). Calcium (150-720 nmol) administered intrathecally (i.t.), 15 minutes prior to measuring rectal temperature, produces hypothermia in intact mice. However, in spinalized mice (with a mechanical block of the cerebrospinal fluid (CSF) flow at the T6-T8 vertebrae) injected i.t., showed no hypothermic response. Calcitonin gene-related peptide (CGRP) modulates intracellular calcium within the brain and the spinal cord. CGRP (53-1051 pmol, i.t.) produced significant dose-dependent decreases in temperature at 3, 12, and 15 hr. with the peak effect at the 3 hr. Calcium (75 nmol) and CGRP (5.3 pmol) in combination synergized to produce hypothermia at the 1 and 3 hr. time points. CGRP given i.t. may diffuse rostrally through the CSF to the brain and modulate calcium in the posterior hypothalamus to produce this hypothermia. This work was supported by grant # DA 06031, F32-DA05415, and Commonwealth Center on Drug Abuse Research.

DEVELOPMENT OF 5-HT₃ SELECTIVE SEROTONIN AGONISTS. M. Dukat, P. Bartyzel, M. Teitler and R. A. Glennon Dept. of Medicinal Chemistry MCV/VCU, Richmond VA 23298. 5-HT₃ serotonin receptors may be of clinical significance in the treatment of migraine, anxiety and nausea and emesis from cancer chemotherapy. To date, there are no potent and selective 5-HT₃ receptor agonists. Using 5-HT as a starting point, we examined the influence of various terminal N-substituents on 5-HT₃ affinity due to evidence that bulky substituents might be tolerated. We also studied the distance between the aromatic ring to the amine because the possibility exists that 5-HT₃ receptors may accommodate ligands with a greater distance than that found in 5-HT. We examined tryptamine analogs (homotryptamines) where the side chain was extended; these bind at 5-HT₃ receptors with low affinity ($K_i > 2,000$ nM). Although bulky amine derivatives also bind with low affinity, quaternary amine analogs of 5-HT bind with increased affinity and selectivity at 5-HT₃ receptors. 5-HTQ, the N,N,N-trimethyl quaternary amine analog of 5-HT, binds with higher affinity ($K_i = 75$ nM) than 5-HT ($K_i = 530$ nM), and is selective for 5-HT₃ versus other 5-HT receptors.

IDENTIFICATION OF THE SIGMA-OPIATE PHARMACOPHORE. M. B. El-Ashmawy^{*} J. D. Smith, A. M. Ismaiel, J. B. Fischer and R. A. Glennon. Dept. of Medicinal Chemistry, MCV/VCU, Richmond, VA 23298 and CNS Research, Cambridge, MA 02139. Sigma (σ) receptors are gaining much attention due to their implication in mental disorders. Unfortunately, σ -selective agents are currently unavailable; for example, the benzomorphan σ -opiates, such as N-allylnormetazocine, bind at σ ($K_i = 429$ nM) and PCP sites. In the present investigation a novel class of high affinity σ -selective agents was designed. We first identified the primary pharmacophore of the benzomorphans as the N-substituted phenethylamine moiety. The structure-affinity relationships of several 1-phenyl-2-aminopropane derivatives and their conformationally-restricted analogs were evaluated and agents of high affinity (e.g. N-(5-phenylpentyl)-1-phenyl-2-aminopropane, $K_i = 6.2$ nM) were designed. The aromatic hydroxyl group, common to most σ -opiates, does not appear to be necessary for binding. Unlike the σ -opiates, the novel compounds display no affinity for PCP sites ($K_i > 10000$ nM) and various other receptors. (Supported by Virginia C.I.T. and CNS Research).

PREGNANCY TOXEMIA DETECTION BY SPECTRAL ANALYSIS OF BLOOD PLASMA. Lyle Evans, & Germille Colmano, Dept. of Biomedical Sciences, VMRCVM, VPI & SU, Blacksburg VA, 24061-0442. Ten blood plasma samples from pregnant women of whom 3 had pregnancy toxemia (preeclampsia, or pregnancy-induced hypertension) were spectrophotometrically scanned from 190 to 650 nm, and the spectral averages of the toxemic and not toxemic sample exhibited differences. For each spectrum the principal components of the small region (50nm) with the highest spectral difference were calculated. Using the first three principal components the samples were then plotted in three dimensions and toxemic and non-toxemic samples became separable by a plane.

³H-MECAMYLAMINE BINDING TO RAT BRAIN HOMOGENATE. Fang Fan and Billy R. Martin, Dept. of Pharmacology and Toxicology, Va. Commonwealth Univ., Richmond, Va. 23298. Mecamylamine can antagonizes almost all the central effects of nicotine. Its mode of action remains unclear although it is certain that it does not act directly at central nicotinic cholinergic receptors. Precious structure-activity relationship study of mecamlamine analogues in our laboratory suggested that the antagonism of mecamlamine involved a receptor-mediated process. The goal of the present study is to characterize the mecamlamine receptor. ³H-Mecamylamine was incubated with rat brain homogenate in 50 mM Tris-HCl buffer (pH 9.0) for 30 min. at 25° C. Non-specific binding was determined in the presence of 1 mM unlabeled mecamlamine. Scatchard analysis revealed two binding sites. The K_D (B_{max}) of the high and low affinity binding sites are 84 nM (98 fmol/mg protein) and 8.9 μM (24 pmol/mg protein), respectively. In displacement study, mecamlamine analogues were tested for their ability to compete with the high affinity binding site. The IC₅₀'s of these mecamlamine analogues were inconsistent with their potency in vivo, which indicated that this high affinity binding sites are not responsible for mediating the antagonistic action of mecamlamine.

ANALYSIS OF COLLAGEN SYNTHESIS AND BREAKING STRENGTH DURING FETAL WOUND HEALING. Frazier W. Frantz, Robert F. Diegelmann, Bruce A. Mast*, I. Kelman Cohen*, Dept. of Surgery, MCV/VCU, Richmond, Va. 23298. *In utero* intervention to correct life-threatening congenital anomalies has mandated a thorough understanding of the mechanisms of fetal healing. In comparison to adult repair, fetal healing involves minimal collagen deposition and no scar formation. In our study, breaking strength (BS) was used as a measure of the restoration of mechanical function in fetal and adult wounds. In addition, collagen synthesis in fetal and adult wounds was analyzed using tritiated proline incorporation into bacterial collagenase-sensitive protein as a measure. Adult wounds demonstrated slow restoration of BS and a 3-fold increase in relative collagen synthesis (RCS) post-wounding. In marked contrast, fetal wounds exhibited rapid BS restoration with no appreciable increase in RCS during the same post-wounding period. These results suggest that fetal repair is functionally, as well as cosmetically, superior to adult wound healing and is successfully accomplished through processes similar or identical to normal fetal development.

CELL MONOLAYER FORMATION IN GLASS TUBES. S. Gallik, T. Plaia*, S. Hamblin*, J. Sloop*, and K. Wright*, Dept. of Biol. Sci., Mary Washington College, Fredericksburg, VA. 22401. The success of cell monolayer formation in glass tubes was determined in order to elucidate the possible use of glass tubes in studies of the effects of fluid flow on adhesion-dependent cells. Balb/3T3 fibroblasts and MDBK cells were seeded at a density of 20,000 cells/cm² into two types of glass tubes: rectangular glass tubes having a parallel-plate geometry (0.04 cm h x 0.8 cm w x 30.5 cm l) and large-bore round glass tubes (0.8 cm diam x 30.5 cm l). Both types of cells were grown in both types of tubes under two conditions: one in which the growth medium was changed every 24 hours and another in which the tubes were continuously perfused under relatively low-shear conditions. In the rectangular glass tubes, both types of cells did not grow to confluent monolayers under either of the growth conditions. In the large-bore round glass tubes, confluent cell monolayer formation was successful for both types of cells under both growing conditions. It is postulated that the large surface area to volume ratio of the rectangular glass tube limits nutrient delivery and therefore limits cell growth.

EFFECTS OF NERVE GROWTH FACTOR ON VOLTAGE-DEPENDENT ENDOGENOUS DOPAMINE RELEASE FROM PC-12 CELLS. John Harms and John J. Woodward, Dept. of Pharmacology and Toxicology, MCV/VCU, Richmond, VA 23298. Neurotransmitter release is an essential component of signal generation in brain neurons and is initiated by the opening of voltage-sensitive calcium channels (VSCC) during depolarization. Brain neurons possess several different types of VSCC with differing sensitivities to pharmacological agents. The clonal cell line PC-12, which secretes dopamine upon depolarization, appears to possess at least two different types of VSCC which can be differentially expressed under different growth conditions. Under normal conditions, PC-12 cells released dopamine during exposure to KCl. Release was concentration dependent with half-maximal release occurring at approximately 35 mM. Stimulation of PC-12 cells with KCl also produced significant increases in intracellular calcium as measured by the calcium indicator dye, fura-2. Both KCl-induced increases in dopamine release and intracellular calcium were potentiated by the dihydropyridine (DHP) calcium channel agonist, Bay K 8644, and were potently inhibited by the antagonist nifedipine. PC-12 cells treated with nerve growth factor (NGF) for four days developed extensive processes and took on a neuronal-like appearance. Under these conditions, KCl-induced dopamine release was still potentiated by Bay K 8644 but was totally resistant to inhibition by nifedipine. These results indicate that NGF treatment results in the expression of a DHP-insensitive calcium channel in PC-12 cells that may be similar to those expressed in neurons and illustrates the usefulness of this cell line as a model for studying neurotransmitter release. (Supported by NIAAA AA08089).

STIMULUS PROPERTIES OF TFMPP: EVIDENCE FOR A SIGMA COMPONENT. J.

L. Herndon, M. E. Pierson, R. A. Glennon, Dept. Medicinal Chemistry, MCV/VCU, Richmond, VA 23298. Using standard two-lever operant procedures with rats trained to discriminate TFMPP (0.5 mg/Kg) from saline, tests of stimulus antagonism and stimulus generalization were performed. The agents examined for ability to antagonize the TFMPP stimulus were prazosin, quipazine, buspirone, 8-OH DPAT, NAN-190, zacopride, haloperidol and 1-PP; only buspirone attenuated the response to TFMPP. In separate experiments, the lowest non-disrupting dose of buspirone (1.2 mg/Kg) caused a rightward shift in the TFMPP dose-response curve (TFMPP alone, $ED_{50} = 0.19$ mg/Kg; TFMPP + Buspirone, $ED_{50} = 0.43$ mg/Kg). In addition, CP 93,129, CGS 12066B, DOI, NAN-190, zacopride, 1-PP, (+)-NANM and MDMA were analyzed in tests of stimulus generalization. Only CGS 12066B ($ED_{50} = 4.2$ mg/Kg) and (+)-NANM ($ED_{50} = 8.8$ mg/Kg) generalized to the TFMPP stimulus. Tests of DOI and MDMA resulted in partial generalization. Up to doses that disrupted behavior, all other agents were inactive. The results of these and other published studies suggest roles for 5-HT_{1B}, 5-HT_{1C}, and sigma receptors in the mediation of the TFMPP stimulus and indicate a lack of involvement of 5-HT_{1A}, 5-HT₂, 5-HT₃, dopaminergic and adrenergic mechanisms in this behavior.

STIMULUS PROPERTIES OF RING-METHYL AMPHETAMINE ANALOGS. R.A. Higgs*

and R.A. Glennon. Department of Medicinal Chemistry, MCV/VCU Richmond. VA 23298. The terms methamphetamine or methylamphetamine are commonly employed to refer to the N-Methyl analog of amphetamine (AMPH), where the methyl group is attached to the terminal amine. There are three possible ring substituted methyl AMPH analogs or tolylaminopropanes (TAPS): oTAP, mTAP and pTAP. These are positional isomers of methamphetamine where the methyl group is attached directly to the aromatic ring. Ring-substituted methylamphetamines have been reported to possess AMPH-like character. Few studies have examined all three agents in comparison with AMPH. Male Sprague-Dawley rats were trained to discriminate 1 mg/kg of (+) AMPH sulfate ($ED_{50} = 0.4$ mg/kg) from saline in a 2-lever operant chamber using a VI - 15s schedule of reinforcement. In stimulus generalization tests, doses of the TAP isomers were administered in a random order. Results of the stimulus generalization studies with oTAP reveal complete stimulus generalization ($ED_{50} = 4.1$ mg/kg). The mTAP and pTAP isomers resulted in partial generalization followed by disruption of behavior. It cannot be concluded that mTAP and pTAP lack amphetamine-like character.

HISTOLOGICAL AND BIOCHEMICAL ANALYSES OF EPIDERMAL GROWTH FACTOR INFLUENCES ON PREPUBERTAL ANTERIOR PROSTATES OF SWISS-WEBSTER MICE. Vincent L. Hottinger, Richard T. Kratz, Stephen A. Johnson, and Roman J. Miller, Dept. of Biol., Eastern Mennonite Col., Harrisonburg, VA 22801. To further define epidermal growth factor (EGF) inhibition on androgen-induced seminal vesicle growth and function, 20 day old prepubertal Swiss-Webster male mice were placed in one of four treatment groups each which received five injections during a 10 day period. (I. BSA&Oil, 0.5 ug/injection; II. EGF, 0.5 ug/inj.; III. DHT, 200 ug/inj.; IV. EGF&DHT, 0.5 ug & 200 ug/inj.). Post treatment seminal vesicles were removed and fixed for histology or homogenized for biochemical analysis. Based on organ wet weight, the EGF group significantly increased 140% from the BSA&Oil group, the DHT group increased over 200%, while the EGF&DHT group was 28% lower than the DHT group. Morphometric analysis of light microscopy plastic-embedded sections assessed glandular, stroma, and lumen components. Glandular volume density ($\text{um}^3 \text{ component}/\text{um}^3 \text{ tissue} \times 10^2$) was significantly higher in the BSA&Oil group and lowest in the EGF group (I = 68.8; II = 47.5). Stroma volume density was significantly higher in the EGF group as compared to other groups (II = 47.2; total mean 27.8). Analysis of the absolute stroma and glandular contents (mg tissue/10 g body weight) for the EGF&DHT group revealed 43% and 18% declines, respectively, from the DHT group. (Research funded by D.B. Suter Biology Endowment.)

A QSAR STUDY OF CHOLECYSTOKININ ANTAGONISTS INCORPORATING EMPIRICAL HYDROPHOBIC INTERACTION CALCULATIONS. Helen L. Jiang, Glen E. Kellogg, & Simon F. Semus, Div. of Biomedical Engineering, Medical College of Virginia, Virginia Commonwealth Univ., Richmond, Va. 23298-0694. Nonpeptidal antagonists of the peptide hormone cholecystokinin (CCK), are highly potent, orally effective ligands for peripheral (CCK-A) receptors. A series of 3-substituted 5-phenyl-1,4-benzodiazepines, with binding affinities approaching or equaling that of the natural ligand CCK-8, were selected from the literature for a QSAR study. Their structures were built and optimized by using the Sybyl suite of molecular modelling programs. The model which associates the biological activity (drug-receptor binding affinity) with the steric, electrostatic and hydrophobic factors is obtained by adding a hydrophobic field into the standard Comparative Molecular Field Analysis (CoMFA). This model is compared to the one obtained from standard CoMFA methods. The hydrophobic atom constants are calculated by using HINT and the hydrophobic field obtained for each individual molecule is imported into Sybyl where it is employed in CoMFA. CoMFA steric, electrostatic and hydrophobic coefficient maps were obtained based on 46 analogs. Improved chemical information, which is helpful for drug-design purposes, is obtained by this method.

MORPHOMETRIC ANALYSES OF CELLULAR AND TISSUE CHANGES IN THE SEMINAL VESICLE OF PREPUBERTAL VERSUS ADULT SWISS-WEBSTER MICE. Judith L. Leatherman, Brent L. Lehman, and Roman J. Miller, Dept. of Biol., Eastern Mennonite Col., Harrisonburg, Virginia 22801. Tissues for light and electron microscopy were fixed in glutaraldehyde and post-fixed in osmium tetroxide prior to embedment in plastic. Light microscopy sections, stained with Toluidine blue, were analyzed and photographed with a Nikon Microphot system at 100x magnification, while electron microscopy sections, stained with uranyl acetate and lead citrate, were viewed with a JOEL 100s transmission electron microscope at 2000-3000x magnifications. In this preliminary study, tissues from 20, 30, and 120 day (d) old mice were examined. Organ wet weights (mg) significantly increased (20 d = 1.4; 30 d = 11.0; 120 d = 84.1) Volume density measures ($\text{um}^3/\text{um}^3 \times 10^2$) for the glandular component of the seminal vesicle averaged 49.5 for all three groups with no statistically significant differences among them. Stroma volume density values progressively declined (20 d = 43.6; 30 d = 30.6; 120 d = 8.3), while the lumen component progressively increased (20 d = 6.4; 30 d = 16.9; 120 d = 44.6). Epithelial cell examination (glandular component) showed that individual cell volume increased about four-fold between 20 and 120 days of age, while nuclear volume did not significantly change. Early pubertal influences largely reflect increases in lumen volumes with secretions and structural changes in glandular epithelium. (Research funded by D.B. Suter Biology Endowment.)

Δ^9 -TETRAHYDROCANNABINOL (Δ^9 -THC) INHIBITS THE ACOUSTIC STARTLE RESPONSE. A.H. Lichtman, R.S. Mansbach, and B.R. Martin Virginia Commonwealth University, Richmond, VA.

Several reports in the literature suggest that administration of Δ^9 -THC and other cannabinoids may have a hyperactive effect in rodents. Therefore, the present study examined the impact of Δ^9 -THC on the acoustic startle response as well as its effects on prepulse inhibition, a phenomenon in which exposure to a weak acoustic stimulus inhibits the response to a louder stimulus presented 60-200 msec later. Rats were administered vehicle or Δ^9 -THC (1, 3, or 10 mg/kg) and twenty minutes later placed in a restraining tube where they were presented with 25 startle trials, some of which consisted of a 122 db startle stimulus alone, and others in which the startle stimulus was preceded by an 80 db prepulse stimulus with durations of 1, 3, or 10 msec. Although Δ^9 -THC failed to affect prepulse inhibition, 10 mg/kg of Δ^9 -THC significantly decreased the startle amplitude to 60% of the vehicle amplitudes. In addition, the underlying pharmacology of Δ^9 -THC-induced inhibition of startle was examined. Subjects were administered either the muscarinic antagonist, atropine (10 mg/kg), or saline and 10 min later injected with Δ^9 -THC (10 mg/kg) or vehicle. They were then assessed for the acoustic startle response, followed by a five min catalepsy test. As previously reported, atropine pretreatment blocked Δ^9 -THC-induced catalepsy, however, it failed to reverse Δ^9 -THC's inhibition of the startle response. These results indicate that Δ^9 -THC's effects on the startle response and catalepsy are mediating through different neurochemical mechanisms. This work is supported by MH-46631 and NIDA grants DA 03672 and DA 07027.

PRENATAL EXPOSURE TO COCAINE AFFECTS SERUM THYMOSIN ALPHA-1 AND THYMUS MORPHOLOGY IN OFFSPRING. Lauren E. McGurk, G. Dawn Royall, Karen K. Oates, Dept. of Biol., George Mason Univ., Fairfax, Va. 22030. Pregnant Long-Evans hooded rats were given daily subcutaneous injections of cocaine on Gestational Days 8-20 of 5, 10, 20, or 40 mg/kg. Control groups included paired/vehicle injected (PF/V) and uninjected (UN) animals. Litters were culled to four sex pairs at birth; blood samples and thymi were obtained from the remainder via decapitation. Neonatal thymus weights of the high dose were 28 percent lower than those of the UN control group. Serum thymosin alpha-1 (Ta-1) levels were quantified by radioimmunoassay. Neonatal Ta-1 levels for the 40 mg/kg group were 18 and 22 percent higher in PF/V and UN groups, respectively. One sex pair from each litter was sacrificed on Postnatal Day 21 (PD21) and similar evaluations were performed. PD21 thymus weights of the high dose group were 23 percent higher than the UN group. Additionally, Ta-1 levels were 22 and 15 percent higher than those of the PF/V and UN controls.

THE EFFECT OF COCAINE ON THE BLOOD PRESSURE AND CEREBRAL BLOOD FLOW IN BRAIN - INJURED RATS. J. K. Muir and E. F. Ellis*, Department of Pharmacology and Toxicology, Medical College of Virginia, Richmond, VA 23298

Cocaine abuse has increased dramatically in the past decade. Besides its marked dependence potential, cocaine also has sympathomimetic properties due to its ability to block synaptic reuptake of norepinephrine (NE). Previous studies have shown that cocaine will potentiate the blood pressure (BP) and cerebral blood flow (CBF) response to exogenous NE. (Muir & Ellis, FASEB J, 5:A675 1991). The purpose of this study was to see if cocaine would alter BP and CBF following fluid percussion injury, since this model of brain injury involves the massive release of NE both centrally and peripherally.

Sprague-Dawley rats (n=17) were initially anesthetized with thiopental (75 mg/kg, ip) and maintained with pentobarbital. The animals were ventilated with room air and blood gases were maintained within normal limits. Two craniectomies were made over each hemisphere and the dura was left intact. The injury device was placed over the right parietal cortex and a laser-Doppler probe for measurement of CBF was positioned over the left parietal cortex. Both were secured with dental acrylate.

Cocaine (2 mg/kg, iv) or saline was administered and ten minutes later the animals received a moderate level of injury (2.0-2.1 atm). Upon injury both groups showed a similar acute hypertensive phase, but this phase was followed by a period of pronounced hypotension in the cocaine group (68 \pm 4 vs 100 \pm 6 mmHg). The BP response recovers and is similar to the saline controls by 20 minutes post injury. CBF also increases dramatically following injury in both groups, but falls below control within minutes. The animals that received cocaine had higher blood flows than the saline group, including the hypotensive phase. One hour post injury, the CBF of the cocaine and saline groups were 28 \pm 7 % and 47 \pm 6 % below control, respectively.

The Effects of Opiate Tolerance on Calcitonin Gene-Related Peptide (CGRP) Levels in Rat Brain Regions. Olson, K. G., Bass, P. P., Welch, S. P., and W. L. Dewey. VA Comm. Univ., Richmond, VA. Animals were implanted with a subcutaneous osmotic minipump containing either morphine sulfate or the distilled water vehicle. Animals receiving the morphine minipump became tolerant to morphine prior to CGRP measurement. Some morphine minipumped animals were also injected twice daily with 2 mg/kg naltrexone which prevented tolerance development. Effects of acute administration were shown by subcutaneous injections of morphine sulfate or naloxone 20 minutes prior to CGRP measurement. Levels of CGRP were measured via radioimmunoassay in the following regions: cerebellum, corpus striatum, cortex, hippocampus, hypothalamus, medulla, midbrain, and spinal cord. Significant differences in CGRP levels were found between morphine tolerant animals and those with a vehicle minipump in the hypothalamus, medulla, midbrain, and spinal cord. In the presence of vehicle minipumps and chronic s.c. injections levels of CGRP were 408, 929, 454, and 527 fmol/mg protein in the hypothalamus, medulla, midbrain, and spinal cord, respectively. These were reduced to 115, 546, 139, and 223 fmol/mg in the respective regions following chronic morphine. Chronic naltrexone in the rats receiving chronic morphine significantly reversed the effects of morphine in the hypothalamus, medulla, and midbrain. No significant effect on CGRP levels was found following acute subcutaneous administration of morphine or naloxone. These data indicate that opiate tolerance decreases CGRP levels in selective brain regions and the spinal cord. These alterations may contribute to the development of tolerance to morphine. Supported by grant # DA06031 and the VA Commonwealth Center for Drug Abuse.

COMPARATIVE MOLECULAR FIELD ANALYSIS OF NON-PEPTIDE ANGIOTENSIN II ANTAGONISTS. M. Edward Pierson, Dept. of Pharmacology and Toxicology, Med. Col. of Va. / Va. Commonwealth Univ., Richmond, Va. 23298. Angiotensin II (AII) is a peptide hormone implicated in the regulation of blood pressure. Recently several series of nonpeptide AII antagonists have been reported. DuP 753, a biphenylimidazole, is the prototypic AII nonpeptide antagonist and it is currently undergoing evaluation as an antihypertensive agent. Using the multifit program in the molecular-graphic platform SYBYL (Tripos) DuP 753 can be overlaid with AII. Comparative molecular field analysis of the benzamidobenzyl- and biphenyl-imidazole nonpeptide angiotensin II antagonists was done for the steric and electrostatic components of these compounds. The C-terminal tetrapeptide portion of AII that DuP 753 is proposed to mimic was also included in this analysis. This type of analysis may lead to a better understanding of how AII interacts with its receptor and provide new insights for development of AII agonists and antagonists.

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BACK PROPAGATION NEURAL NETWORK MODEL USING SPICE. Jeffrey A. Prideaux, BME Program MCV/VCU, P.O. Box 694 Richmond, VA. 23298-0694. SPICE, an electrical circuit simulator, will be used to simulate a back-propagation neural network. The network will attempt to learn the x-or function, which is the simplest non-linear separable problem. Some advantages and disadvantages in using an analog circuit simulator will be discussed along with some similarities and differences between this neural network and real biological networks. The challenge is not modeling how the neurons intercommunicate, but how they "learn" (change structure or connection strength).

ALLOSTERIC INHIBITORS OF HEMOGLOBIN: DESIGN AND COMFA STUDY.
Ramnarayan S. Randad, Glen E. Kellogg, Fred C. Wireko and Donald J. Abraham.
Department of Medicinal Chemistry. Medical College of Virginia, VCU, Richmond, VA 23298.

Allosteric Inhibitors of hemoglobin (Hb) facilitate dissociation of oxygen bound to Hb. Recently we have reported three series of potent allosteric inhibitors of Hb¹. The binding sites of the new compounds have been determined crystallographically². We now report QSAR studies using the computer program COMFA using three fields, electrostatic, steric, and hydrophobic.³

1. Randad, R.S., Maharan, M.A., Mehanna, A.S. and Abraham, D.J. *J. Med. Chem.* **1991**, *34*, 752.
2. Wireko, F.C., Kellogg, G.E., Abraham, D.J. *J. Med. Chem.*, **1991**, *34*, 758.
3. Kellogg, G.E., Semus, S.F., Abraham, D.J. *J. Computer-Aided Mol. Design* (in press).

PRENATAL EXPOSURE TO COCAINE AFFECTS SERUM PROLACTIN AND GROWTH HORMONE IN OFFSPRING. G. Dawn Royall, & R. F. Smith*, Dept. of Psych., George Mason Univ., Fairfax, Va. 22030. Pregnant Long-Evans hooded rats received daily SC injections of 5, 10, 20, or 40 mg/kg of cocaine on GD 8-20; controls included pairfed/vehicle injected (PF/V), and uninjected (UN) groups. Serum PRL and GH levels obtained from neonates sacrificed at birth via decapitation were quantified by radioimmunoassay (RIA) with reagents obtained from the National Pituitary Hormone Distribution Program of the NIDDK and evaluated against the rPRL-RP-3 and rGH-RP-2 reference preparations. Significant dose-dependent decreases in serum levels of PRL and GH were observed. Neonatal concentrations of PRL in the 40 and 20 mg/kg groups were 22 and 18 percent, and 18 and 16 percent less than those of the UN and PF/V control groups, respectively. In contrast, neonatal concentrations of GH in the 10 and 5 mg/kg groups were 37 and 38 percent, and 28 and 30 percent less than those of the UN and PF/V control groups, respectively.

THE RELATIONSHIP OF CALCITONIN GENE-RELATED PEPTIDE, PROTEIN EXTRAVASATION AND HEAT NOCICEPTIVE THRESHOLD AFTER ACUTE SKIN INCISION IN THE MOUSE HINDPAW. M. SAXEN, S. WELCH, and W.L. DEWEY, Dept. of Pharmacology/Toxicology, Virginia Commonwealth University, Medical College of Virginia, Richmond, VA 23298. Calcitonin Gene-Related Peptide (CGRP) exists in abundance in the free nerve endings of primary afferent nerves and is thought to act locally to alter nociceptive threshold. We designed experiments to determine if a relationship exists between the amount of CGRP in dorsal hindpaw mouse skin and heat nociception. RIA was used to quantitate CGRP levels in skin, dye spectroscopy for protein levels, and a modification of the tail flick assay for threshold levels. Protein as a % of weight dropped to 68% of control 1 hr after incision before returning to control levels at 3 hrs. CGRP dropped to 47% of control at 1/2 hour and remained at 61% and 63% of control at 1 hr and 3 hr respectively. Heat nociceptive threshold rose to 125% of control at 1/2 hr, 122% of control at 1 hr, and returned to control level at 3 hrs. These data demonstrate the lack of a direct relationship between CGRP and heat nociceptive threshold in the first 3 hrs. after skin incision. An inverse relationship exists between % protein and heat nociceptive threshold. This work was supported by NIDA grants DA06031, DA01647 and NIDR grant DE00151.

THE EFFECT OF HOLOTHURIN ON TRYPANOSOMA MUSCULI INFECTION IN AN INBRED FN STRAIN OF FEMALE MICE. Dilip K. Sen, Lora Wan, Hunter D. Hamlett and William R. Jones, Dept. of Biol., Va. State Univ., Petersburg, Va 23803. This study was conducted to investigate the effect of a marine biotoxin, holothurin (a saponin of animal origin), on infection caused by Trypanosoma musculi in an inbred FN (fawn) strain of female mice. In previous studies (Sen and Lin 1977, Sen et al. 1981), various strain of mice were shown to have increased their resistance for this sterocorarian hemoflagellate when a holothurin inoculum was administered. The results indicated in the present study that the drug treated mice had fewer parasites in the peripheral circulation than the untreated control group. The parasitemias in all experimental groups showed a significant difference at the 5% level as compared with their untreated control counterpart.

EFFECT OF DEHYDROEPIANDROSTERONE (DHEA) ON THE ULTRASTRUCTURE OF Nb2 LYMPHOMA CELLS. Yanal Shafagoj, Milton Sholley, and Mohammed Kalimi, Depts. of Anatomy and Physiology, Medical College of Virginia, Virginia Commonwealth University, Richmond, VA 23298. We previously reported that DHEA induces cytoplasmic granules in cultured human endothelial cells. The granules were identified as multilamellar lipid structures (MLL), which are secondary lysosomes containing phospholipid membranes and free cholesterol. We have now found that DHEA also induces MLL in Nb2 lymphoma cells. Nb2 cells were incubated for 24 or 72 hours in culture media containing 1 or 50 μ M DHEA in 0.25% DMSO or 0.25% DMSO alone (control). Cells were pelleted, prepared for electron microscopy, and photographed with a JOEL JEM-1200 electron microscope. Prints were analyzed with a Zeiss MOP-3 image analyzer. Parameters measured were cytoplasmic area, area of MLL, and area of neutral lipid (NL) droplets. There were no significant differences between any of the parameters for cells in medium alone, control medium, or medium containing 1 μ M DHEA. Interestingly, 50 μ M DHEA-treated cells showed significantly ($P < 0.05$) greater areas of MLL at both 24 and 72 hours; NL was significantly greater at 72 but not at 24 hours. In addition, the same significant differences were found when MLL and NL were expressed as ratios to cytoplasmic area. It is concluded that DHEA at a high dose elevates the content of lipid-associated organelles in Nb2 lymphoma cells. The mechanism and significance of this phenomenon remains to be determined. *Supported by Elan Corporation, Ireland.*

ANALYSIS OF cDNA CLONES OF SCHISTOSOMA MANSONI. Maryanne C. Simurda, J. Kenyon, M. Lubkowitz. Dept. of Biol. Washington & Lee Univ. Lexington, Va. 24450. Various procedures were used to isolate clones from a cDNA library of the adult stage of S. mansoni in order to study antigens important in the disease process of this human blood fluke. One clone, pSMSOD, from this collection has been characterized and the amino acid sequence derived from the mRNA sequence shows about 40% homology with the known sequences for the enzyme superoxide dismutase. Amino acids crucial for the activity of this enzyme are conserved. Interestingly, this sequence contains a potential hydrophobic signal sequence for secretion. The protein product, resulting from the *in vitro* translation of the hybrid selected mRNA, is immunoprecipitable with sera from human patients with a chronic infection and enzyme analysis of adult worms shows superoxide dismutase to be associated with the parasite's tegument. Other current work involves the initial characterization of other cDNA clones: pSML4, pSML7, pSM4-28, by restriction enzyme mapping, DNA sequencing, and genomic DNA Southern Blot analysis.

SELECTIVE PROTECTION BY GANGLIOSIDE FOLLOWING EXPERIMENTAL BRAIN INJURY IN RATS. Amrita K. Singha, Robert J. Hamm, Clifton E. Dixon, Brian R. Pike, & Ronald L. Hayes. Depts. Psychology and Neurosurgery, Va. Commonwealth Univ., Richmond, Va. 23298. The present study examined the effectiveness of pretreatment with ganglioside (GM₁) on mortality, motor, and cognitive deficits following a fluid percussion injury. Rats were moderately injured (2.25 atm) and received either GM₁ (n=8-10) (30 mg/kg, i.p.) or saline (n=7-8) (1 ml/kg, i.p.) for 3 days prior to injury. Immediately following injury, rats were assessed for their acute neurological responses. Chronic motor responses were evaluated for 5 days after injury using the beam balance and beam walk. These tasks assess motor impairments where the latency of the animal to walk or balance on the beam is measured. Animals were additionally evaluated for cognitive function using the Morris water maze on days 11-15 after injury. The water maze measures spatial memory indicated by the rat to locate a hidden goal platform. Results revealed a selective protection for the GM₁ treated rats. Animals treated with GM₁ had a significantly lower mortality rate than the saline-treated animals. There were no significant group differences on acute neurological, motor, or cognitive responses. These observations suggest that treatment with GM₁ prior to injury may be therapeutic in increasing survival rates, but it is ineffective in reducing behavioral deficits observed after injury.

CHARACTERIZATION OF THE MAJOR HYDROLYSIS PRODUCTS OF AMOBARBITAL N-GLUCOSIDES. E.B. Vest*, W.H. Soine, and R.B. Westkaemper, Dept. Med. Chem., Va. Commonwealth Univ., Richmond, Va. 23298-0540. Phenobarbital (PB) N-glucosides have been observed to decompose via ring opening under conditions in which no decomposition of PB occurs. Structurally related amobarbital N-glucosides (AMG-R and AMG-S) are urinary excretion products of amobarbital (AM), but the decomposition products of these metabolites have not yet been identified. The decomposition products of the AM N-glucosides were prepared by dissolving AMG-R or AMG-S in 0.10M TRIS buffer at pH 7.4 and heating the mixtures at 37 °C for a period of 34 days (12 half-lives). The reaction mixtures were monitored by HPLC using a mobile phase of CH₃CN:H₂O (30:70, v:v) at a flow rate of 1.0 ml/min with detection at 198 nm. The major decomposition product was observed in the solvent front for both epimers. It was anticipated that the ring opened product contained a carboxylic acid, so the reaction mixture was treated with BF₃·MeOH to form the methyl ester derivative. Major peaks eluting at 10 and 11 min were shown by HPLC analysis for the R and S epimers of the AM N-glucosides, respectively. The products were purified by semi-preparative HPLC. Based on IR, NMR, and UV studies, the product for both epimers was determined to be 3-(1-β-D-glucopyranosyl)-3-(2-ethyl-2-(3-methyl)butylmalonyl)urea methyl ester, which is different ring opening from what was observed for PB N-glucoside decomposition. (Supported by NIH grant GM 34507.)

GRANULOCYTE-MACROPHAGE COLONY-STIMULATING FACTOR AND MACROPHAGE COLONY-STIMULATING FACTOR CONTRIBUTE TO MACROPHAGE-MEDIATED SUPPRESSION OF CD4+CD8- T CELL AUTORECOGNITION DURING TUMOR GROWTH. T.M. Walker and K.D. Elgert. Dept. of Biology, Microbiology & Immunology Section, Va. Polytechnic Inst. & State Univ., Blacksburg, VA 24061. Autoreactive T lymphocytes (ATLs) are CD4+CD8- T cells that respond to syngeneic MHC Ia antigens. Macrophages (Mφ) are stimulatory cells for ATLs because Mφ express Ia antigens and secrete regulatory cytokines. Tumor growth disrupts autorecognition by altering Mφ Ia expression, but tumor-induced cytokine alterations are poorly understood. Colony-stimulating factors (CSFs) are secreted by both Mφ and T cells, and the present study assesses their contributions to autoreactivity during tumor growth. Autorecognition by normal host (NH) ATLs and Mφ was altered with granulocyte-Mφ CSF (GM-CSF) and Mφ CSF (M-CSF), but autorecognition using NH ATLs and tumor-bearing host (TBH) Mφ was unaltered by GM-CSF and M-CSF. Indomethacin reversed some tumor-induced suppression, but with GM-CSF and M-CSF only a small additive effect was observed. GM-CSF and M-CSF did not reverse suppression induced by additional TBH Mφ, and suppression was higher when high doses of GM-CSF or M-CSF were used with high percentages of TBH Mφ. These data suggest GM-CSF and M-CSF do not reverse tumor-induced Mφ-mediated suppression of T cell autorecognition.

Parenterally Administered Xanthan Gum Lowers Blood Glucose in Mice

C.R. Ward, D.A. Brase and H.L. Tripathi, Dept. of Pharmacol. and Tox., MCV/VCU Richmond, VA 23298

Arabic, guar, locust bean, tragacanth and xanthan gums were tested for possible hypoglycemic effects in male ICR mice after parenteral administration. Glucose levels were measured in serial blood samples taken hourly from the retro-orbital sinus after i.p. saline (10 ml/kg), insulin (1 U/kg) and gum (50 mg/kg). Insulin and xanthan were the only agents tested that significantly lowered blood glucose; however, the xanthan had a much slower onset (≥ 2 hr) and a much longer duration (≥ 24 hr) than insulin. Xanthan had an ED-50 of 2.5 mg/kg (at 7hr) and a maximum decrease of 55% from basal blood glucose. Oral, i.v. and s.c. routes were also investigated, with only the i.v. and s.c. routes resulting in hypoglycemia. The lag period was present even after i.v. administration, indicating that time is needed for an active metabolite or an endogenous mediator to form. The hypoglycemic effect of xanthan was greatly attenuated in mice rendered diabetic by streptozotocin (STZ) pretreatment, but xanthan normalized blood glucose for 24 hr in genetically diabetic C57BL/KsJ (db/db) mice. Mice pretreated 5 hr with xanthan showed a significant increase in glucose tolerance; however, 5 hr pretreatment with xanthan did not significantly affect serum insulin in ICR mice when compared to controls, but significantly lowered insulin in the hyperinsulinemic (db/db) mice. Thus, xanthan appears to lower blood glucose by both an insulin-dependent mechanism, as indicated by experiments with STZ-diabetic mice, and an insulin-independent mechanism, as indicated by serum insulin measurements. (Supported in part by the Commonwealth of Virginia Center for Drug Abuse Research.)

INJUSTICES IN HUMAN GENETICS. Lisa C. Wisniewski, and J. I. Townsend, Dept. of Human Genetics, Va. Commonwealth Univ./Medical College of Va., Richmond, Va. 23298. Information about women who have made important contributions to our basic knowledge of genetics is virtually non-existent. Barbara McClintock, the 1983 Nobel Prize recipient, is a recent exception. Yet her remarkable discovery of transposable elements was not recognized for almost 40 years. This fate is not unlike that of the father of genetics, Gregor Mendel. Acceptance of Mendel's work came only after other scientists reached the same conclusions as Mendel and attempted to publish them without citing him. Likewise, some scientists presented findings in other organisms unquestionably related to McClintock's work on maize and did not cite her. It is ironic that the very reason neither Mendel nor McClintock were recognized for their brilliance is in fact the greatest compliment of all. Both of these scientists were so far ahead of their time that their colleagues could not fathom, much less support their findings. We believe that oversights suffered by McClintock and other female scientists as well as by Mendel will be much less likely to reoccur if scientists scrutinize the work of their colleagues with an eye for the potential implications of the findings, rather than just a critical eye for disbelief of the unknown or unfathomable.

Microbiology

ERWINIA CAROTOVORA: FUSIONS BETWEEN *pelA* AND *pelB* HAVE PECTOLYTIC ACTIVITY. Lyudmil S. Antonov and George H. Lacy, Lab. Molec. Biol. of Plant Stress, Dept. Pathol. Physiol. Weed Sci., Virginia Polytechnic Institute and State Univ., Blacksburg, VA 24061-0330.

The plant soft-rot bacterium *Erwinia carotovora* subsp. *carotovora* (Ecc) contains three (or four in some strains) genes coding for pectate lyases (PLs). The PL genes *pelA* and *pelB*, coding for highly basic PLs (pI 9.28 and 11.44), are located next to each other on the Ecc chromosome and were cloned on a single plasmid in *E. coli* where they are expressed and their products retain the ability to degrade polygalacturonic acid (PGA). We subcloned each isogene into a different *E. coli* plasmid and sequenced them. For most of their lengths, the two genes are homologous to each other and to the PLbc family of *Erwinia* extracellular enzymes. However, the 3'-terminal part of *pelB* is unique and, therefore, can be used as a probe, specific for this gene. We also constructed the fusion genes *pelAB* and *pelBA* by joining at a *Bgl*III site, respectively, the 5' part of *pelA* with the 3' part of *pelB* and the 5' part of *pelB* with the 3' part of *pelA*. The fusion proteins degrade PGA when expressed by *E. coli* as evidenced by IEF and SDS-PAGE with activity staining. Partial genes also expressed active PLs; this may be important in connection to the possible mechanism of origin of the PL isozymes.

UV AND PEROXIDE RESISTANCE IN DEEP SUBSURFACE BACTERIA. A. A. Arrage* & R. E. Benoit, Dept. of Biol., Va. Polytechnic Inst. & St. Univ., Blacksburg, VA 24061, & T. J. Phelps*, Inst. for Applied Microbiol., Univ. of Tenn., Knoxville, TN 37932. The UV resistance trait was screened in 60 non-sporeforming deep subsurface soil bacteria isolated from depths of 150 - 500 m near the Savannah River Plant in South Carolina. Controls included Tennessee surface soil and ATCC reference bacteria. After millions of years of evolution in the deep subsurface habitat, some aerobic, gram +, pigmented bacteria tolerated high levels of UV radiation when compared to the survival of control bacteria. In general, subsurface microaerophilic bacteria were more sensitive to UV than some subsurface aerobic and control bacteria. Photoreactivating activity was detected in some subsurface bacteria exposed to 365 nm light. The UV and peroxide resistance of some subsurface isolates were related. Given the slow *in situ* rate of bacterial growth and metabolism in the deep subsurface, UV radiation resistance may reflect a general protective mechanism against free radical damage to cell components in deep subsurface microorganisms.

EFFECT OF IMMUNOMODULATION BY NITROSOUREAS IN THE SUCCESSFUL TREATMENT OF CANCER. Victoria Baldwin, Aruna Seth, Prakash S. Nagarkatti and Mitzi Nagarkatti. Department of Biology, Virginia Polytechnic Inst. & State Univ., Blacksburg, Va 24061.

Earlier studies from our laboratory have demonstrated that the chemotherapeutic efficacy of nitrosoureas such as BCNU, Chlorozotocin (CLZ), and Streptozotocin (STZ) depends on their immunomodulating properties (Cancer Res. 49 :6587, 1989). In the current study, we extended these observations to other nitrosourea congeners such as MeCCNU, PCNU and ACNU. It was observed that BCNU, ACNU, PCNU and MeCCNU were highly tumoricidal *in vitro* and *in vivo* whereas STZ was less tumoricidal. Injecting 20mg/kg bodyweight of BCNU, MeCCNU, PCNU and ACNU cured 75-100% of the tumor-bearing mice, whereas, STZ failed to cure tumor-bearing mice. When nitrosoureas were tested for their immunomodulating properties, it was observed that MeCCNU, PCNU and ACNU suppressed the T cell responsiveness to ConA, anti-CD3 mAb and anti- α BTCT mAb by ~60-70%, similar to the immunosuppression mediated by BCNU. In contrast, STZ failed to bring about significant immunosuppression. Lastly, 5-FU, a different anticancer drug was found to be highly tumoricidal but nonimmunosuppressive and was found to cure only 60% of the tumor-bearing mice. These data are consistent with our earlier hypothesis that in the LSA tumor model, nitrosoureas with immunosuppressive activity also inhibit the tumor-specific T suppressor cells thereby permitting the tumor specific CD4⁺ and CD8⁺ T cells to mediate tumor-rejection. In contrast, nitrosoureas such as STZ, or other anticancer drugs such as 5-FU which are less immunotoxic, fail to inhibit the T suppressor cell activity thereby permitting the tumor cells spared from the drug activity, to regrow and kill the host. (Supported in part by NIH grants CA45009 and CA45010).

MECHANISMS FOR CALMODULIN REGULATION OF PHOSPHORYLASE KINASE ACTIVITY. P.K.

Bender and R. Lanciotti*. Dept. of Biochemistry, Va. Polytechnic Inst., Blacksburg, VA 24061. The interaction between the phosphorylase kinase catalytic subunit, γ , and its integral calmodulin subunit mediate the calcium regulation of the enzyme. An unique feature of this interaction is that in the absence of calcium calmodulin inhibits γ activity while in the presence of calcium the enzyme is activated, although, the calmodulin remains bound. Within γ , two calmodulin binding domains have been identified. These two domains are separated by approximately 14 amino acids. We are investigating the role each of these domains and the 14 amino acid inter-domain sequence have in mediating the calmodulin regulation of γ activity. For these studies, we are expressing wild type and mutant γ protein in the baculovirus/insect cell culture system. Using synthetic polypeptides of the inter-domain sequence we have demonstrated that this sequence is an inhibitor of wild type γ activity. We propose a mechanism for the calcium independent calmodulin regulation of γ by invoking an interaction of each calmodulin binding domain in γ with a different calmodulin head region. This places the inter-domain sequence into the catalytic site. Addition of calcium leads to the conventional model for calmodulin binding involving interactions of both calmodulin heads with only one γ domain and displacement of the inter-domain sequence from the catalytic site. Supported by grant #J-236 from Jeffress Tr.

PROTEIN INTERACTION WITH PARVOVIRUS TERMINI I. CELLULAR AND VIRAL PROTEINS INTERACT SPECIFICALLY WITH BOTH BOVINE PARVOVIRUS TERMINI. Virginia R. Braddon, Muriel Lederman, Dept. of Biology, Va. Polytechnic Inst. and State Univ., Blacksburg, VA 24061. The BPV origins of replication are within the double-stranded, hairpinned termini of the single-stranded genome. Replication requires nicking of the termini by virally-coded proteins and a cellular factor that is active during S-phase of the cell cycle. Gel retardation assays using radiolabelled left terminus of BPV and proteins in a 1M NaCl extract of nuclei from BPV-infected, synchronized bovine fetal lung cells show the formation of three specific DNA-protein complexes. The first is caused by interaction with a viral capsid protein, the second by interaction with a non-structural protein and the third by interaction with a cellular factor that is present in five-fold higher concentration in synchronized cells than in contact-inhibited cells. Gel retardation assays using radiolabelled right terminus of BPV and proteins in a 1M NaCl extract of nuclei from uninfected, synchronized BFL cells show a single DNA-protein complex. Competition assays indicate this cellular factor interacts with both termini of BPV and is a candidate for the S-phase protein required for replication.

PROTEIN INTERACTION WITH PARVOVIRUS TERMINI. II. CELLULAR PROTEINS OF DIFFERENT CELL TYPES INTERACT WITH DIFFERENT PARVOVIRUS TERMINI. Catherine M. Deville, and M. Lederman, Dept. of Biol., Va. Polytechnic Inst. and State Univ., Blacksburg, Va. 24061. Dependent parvoviruses, such as adeno-associated-virus (AAV), require a helper virus for productive infection, while the autonomous parvoviruses, like bovine parvovirus (BPV), only need an S-phase factor for progeny formation. AAV, however, can replicate autonomously in synchronized HeLa cells, suggesting that the S-phase factor substitutes for the helper virus. To investigate the nature of this cellular S-phase factor, we performed DNA retardation assays with uninfected nuclear extracts of hydroxyurea-synchronized cells and radiolabeled parvoviral termini in their hairpinned conformation. It has previously been demonstrated that a cellular protein of bovine fetal lung (BFL) cells, a tissue culture host for BPV, interacts with these forms of the BPV left and right terminus (whose sequence and conformation differ). Proteins of HeLa extracts also caused gel retardation of the BPV left *ori*, and of a deleted AAV terminus. Proteins of this extract do not bind to the right end of BPV. Preliminary characterization of the proteins bound to the BPV left *ori* has been carried out by SDS-PAGE electrophoresis of the retarded complexes. The protein gels showed a protein of ~ 54 kd in the BFL/BPV complex, and two phosphoproteins of ~ 55 and 90 kd in the HeLa/BPV complex.

CHARACTERIZATION OF BOVINE PARVOVIRUS TRANSCRIPTS BY THE POLYMERASE CHAIN REACTION. Nanette Diffoot, Robert C. Bates, Muriel Lederman Dept. of Biol., Va. Polytech. Inst. and State Univ., Blacksburg, Va. 24061. A transcription map for bovine parvovirus (BPV) has not been developed. Construction of BPV cDNAs by conventional methods has proven to be a difficult task due to low concentrations of viral transcripts in BPV-infected cell lysates. Amplification of BPV low abundance mRNAs has been possible by the polymerase chain reaction. Previous experiments have demonstrated that, like the human parvovirus B19, all BPV transcripts initiate from one promoter; these promoter sequences are located at map unit 4 (P4). Therefore, a primer containing nucleotide sequences of the expected cap site and internal BPV-specific primers were used to amplify the 5' ends of the transcripts. The 3' ends were amplified with other BPV specific primers and a universal T17 primer. DNA fragments containing sequences from the major BPV open reading frames have been obtained and are in the process of being cloned. Several clones containing BPV cDNA fragments have been sequenced. Three splice sites have been identified, one of which could represent a major splice site of the mRNAs for the viral nonstructural proteins.

EFFECTS OF MEDIA ALTERATIONS ON SWARMING IN *Proteus* spp. Kevin Dixon & Anne Lund, Dept. of Biology, Hampden-Sydney College, Hampden-Sydney, VA 29343. In broth culture *Proteus* cells are short motile rods of slightly greater than 1 μm in length, but on solid media, the cells can be up to 80 μm long, migrating in regular cycles across the surface of plates. This swarming phenomenon is associated with slime production and is a multicellular behavior. *Proteus mirabilis* fails to swarm on nutrient agar which normally contains no added NaCl. On trypticase soy agar (TSA) that is commercially prepared, *P. mirabilis* swarms later after inoculation and more slowly (measured by distance between migration rings) than on TSA prepared by us. Reducing the NaCl concentration of lab-prepared TSA by increments decreases swarming and causes irregular patterns in normally concentric rings of migration around the inoculum. However, if cells are selected from swarming areas on low NaCl plates and inoculated onto low NaCl plates, swarming occurs sooner, migration rings are more concentric, and the slime layer is thinner compared to controls. The amount of NaCl in media necessary for swarming to occur was determined. Observations were made of *P. vulgaris* inoculated onto experimental TSA as well. Flagella stains were prepared.

CHARACTERIZATION OF DNA ASSOCIATED WITH UNSTABLE CLONES FROM THE STAPHYLOCOCCAL CONJUGATIVE TRANSFER REGION. Denise Michelle Eaton and Gordon L. Archer*, Dept. of Microbiology and Immunology, Va. Commonwealth Univ., 23298-0678. The conjugative transfer region (tra) of the staphylococcal antibiotic resistance plasmid pG01 has been identified. When the cloned tra region is introduced into *S. aureus*, only deleted transformants are obtained. Subclones of the region which deletes cannot be introduced into *S. aureus* by protoplast transformation or by electroporation. This phenotype, characterized by the inability to be transformed, has been named Itr. Exonuclease III was used to create deletions of the cloned tra region in *E. coli*. These deletions were screened for Itr in *S. aureus* by electroporation. The portion of the tra region conferring Itr was identified by deletions which could be transformed. DNA sequence analysis of the region revealed an open reading frame that may encode the product responsible for this phenotype. Characterization of this region will elucidate the role of this open reading frame and possible cis-acting sequences in transformation of the tra region.

PHOSPHO-HISTIDINE PHOSPHATASE ACTIVITY IN RAT LIVER. Brenda Faiola and Peter J. Kennelly, Department of Biochemistry and Nutrition, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061. A homopolymer of histidine, average degree of polymerization approximately 125, was partially phosphorylated by chemical means (approximately one in nine histidines as phosphohistidine) and used to ask whether phosphohistidine specific protein phosphatase activity was present in rat liver tissue. It was found that rat liver did indeed contain such an activity. It resided in a soluble protein that was dependent upon divalent metal ions for activity. Mg^{2+} , Mn^{2+} , and Co^{2+} all activated the enzyme with the corresponding order of effectiveness, while Ca^{2+} , Ni^{2+} , Cu^{2+} , and Fe^{2+} had no effect. Zn^{2+} , NaF, and EDTA inhibited the enzyme. The alkaline phosphatase inhibitor tetramisole did not inhibit it, neither did the acid phosphatase inhibitor tartrate or the tyrosine phosphatase inhibitor orthovanadate. Microcystin, which potently inhibits protein phosphatases 1 and 2A, was also ineffective. Gel filtration chromatography has produced an initial estimate of molecular weight of 66,000 daltons. Based on its size, metal ion dependence, and inhibitory signature, we conclude that this phospho-histidine phosphatase is protein phosphatase 2C, an enzyme previously discovered by virtue of its phospho-serine phosphatase activity. To our knowledge, this represents the first report of the existence of a phospho-histidine protein phosphatase.

THE EFFECT OF CARBON SOURCES ON EXPRESSION OF CARBOHYDRATE CATABOLIC ENZYMES AND THE PRODUCTION OF AGROCIN 84. J.V. Formica, Dept. Microbiol. & Immunol., Va. Commonwealth Univ., Richmond, Va., 23298. The nucleotide bacteriocin (agrocin 84) produced by Agrobacterium radiobacter K 84 controls crown gall disease caused by some biovar 1 and 2 strains of A. tumefaciens but not biovar 3 strains. The basis for this difference is not well understood; consequently, the effect of carbon sources on growth, enzyme expression and agrocin 84 production was evaluated. Growth was monitored turbidometrically in a chemically defined medium and agrocin 84 production was assessed by well-diffusion assay. Mannitol was the better carbon source for growth, but fructose was the better source for production. Growth could not be uncoupled from production. Enzyme activities measured at 340 nm in cell extracts of strains C 58 (biovar 1), K 84 (biovar 2) and CG 49 (biovar 3) revealed key enzymes of the HMP but not the EMP as expected. Surprisingly, only strain K 84 lacked key enzymes of the ED pathway. The three strains grew in mannitol but lacked cytosolic mannitol kinase and dehydrogenase, suggesting a membrane-associated activation of mannitol.

GLUCOSE CATABOLISM IN EUBACTERIA ISOLATED FROM NITROGEN-FIXING AZOLLA. Gina Gibson, Brian Shannon, James Gates and Sara McCowen. Department of Biology, VA Commonwealth Univ., Richmond, VA 23284. We previously identified eubacteria isolated from leaf cavities of N-fixing Azolla as members of the genus Arthrobacter. Although data on carbohydrate metabolism in arthrobacters are sparse, two distinct groups have been identified. A few species have been reported to employ the Entner-Doudoroff (ED), rather than the Embden-Meyerhof (EM) pathway used by the type species, A. globiformis. Cell extracts of Arthrobacter isolated from Azolla caroliniana and A. filiculoides were assayed for activity of key glycolytic enzymes. The specific activity of phosphofructokinase of the EM pathway and two enzymes unique to the ED pathway, 6-phosphogluconate dehydratase and 2-keto-3-deoxy-6-phosphogluconate aldolase, were determined. The presence of phosphofructokinase activity and absence of induced levels of ED enzyme activity provide strong suggestive evidence that the EM pathway is the major route of glucose catabolism in these organisms. (Supported by the Undergraduate Research Grant Program of Va. Commonwealth Univ.)

MEPRIN-A AND -B: TWO METALLOPROTEASES OF THE MOUSE KIDNEY. Carlos M. Gorbea and Judith S. Bond, Dept. of Biochem., Va. Polytechnic Inst. and State Univ., Blacksburg, Va. 24061. Meprin-A and -B are disulfide-bridged, tetrameric metalloendopeptidases in renal brush border membranes. Meprin-A contains α -subunits of 90 kDa, and it is expressed in random bred and some inbred strains of mice. Meprin-B contains β -subunits of 110 kDa, and, it has been purified from mice that do not express α -subunits. It is expressed, however, in all mouse strains. Lectin blotting revealed that random bred mice express three oligomeric proteins of approximately 390, 440, and 490 kDa as determined by SDS-PAGE in the absence of reducing agents. Western blotting with either anti- α monoclonal antibodies or anti- β polyclonal antibodies indicated that the 390 and 490 kDa complexes are homotetramers composed of α_4 and β_4 , respectively. In contrast the 440 kDa molecule is a heterotetramer composed of disulfide-linked α and β subunits. (Supported by NIH Grant DK19691)

T CELL RECEPTOR-INDEPENDENT ACTIVATION OF CYTOLYTIC ACTIVITY OF CYTOTOXIC T LYMPHOCYTES MEDIATED THROUGH CD44. Lisa Gote, Aruna Seth, Prakash S. Nagarkatti and Mitzi Nagarkatti. Department of Biology, Virginia Polytechnic Inst. & State Univ., Blacksburg, Va 24061. CD44 is a transmembrane glycoprotein found on a variety of cells including those of myeloid and lymphoid origin. The CD44 molecule has been recognized to be identical to three other molecules: ppg-1, Hermes and extracellular matrix receptor type III. CD44 is highly conserved among various species, although its exact function in different cell types is not clear. In the present study, using a CD44⁺ $\alpha\beta$ TCR⁺ tumor-infiltrating CTL clone, we demonstrate that mAb against CD44 can activate the lytic potential of the CTL clone and redirect the lysis to antigen-negative Fc receptor (FcR)-positive target cells, similar to mAb directed against the $\alpha\beta$ TCR or CD3. In contrast, mAb against CD45R, CD8 and J11d molecules expressed on the CTL clone, failed to activate the lytic activity. Also, the mAb against CD44 could inhibit the TCR-mediated lysis of antigen-specific targets. In contrast, mAb against $\alpha\beta$ TCR [F(ab')₂ fragments] failed to inhibit the CD44-mediated lysis of non-specific targets. Together, these data suggest that binding of CD44 to its ligand on a target cell in the absence of TCR occupancy, may be sufficient to trigger the cytotoxic potential of the CTL leading to lysis of the antigen-negative target cells. Recent studies have shown that the CD44 molecule may bind to specific ligands on endothelial cells and within the extracellular matrix. Thus, binding of the CD44 molecule, expressed on the CTL, to endogenous ligands such as those expressed on endothelial cells, may activate the CTL leading to expansion and lysis of such cells at sites of tissue inflammation. (Supported by NIH grants CA45009 and CA45010).

CD4⁺CD8⁻ THYMOCYTES FROM MRL-LPR/LPR MICE EXHIBIT ABNORMAL PROPORTIONS OF $\alpha\beta$ -TCR⁺ CELLS AND DEMONSTRATE DEFECTIVE RESPONSIVENESS WHEN ACTIVATED THROUGH THE TCR. V.N. Kakkanaiah, Mitzi Nagarkatti and Prakash S. Nagarkatti. Department of Biology, Virginia Polytechnic Inst. & State Univ., Blacksburg, Va 24061.

MRL-lpr/lpr (lpr) mice develop profound lymphadenopathy resulting from the accumulation of CD4⁺CD8⁻ (double-negative, DN) cells in the peripheral lymphoid organs. The source and mechanism of this abnormal accumulation of cells is not clear. In the present study, we investigated the TCR phenotype of DN thymocytes and their responsiveness to activation through the TCR, in lpr mice. The DN thymocytes of MRL +/+ mice and young lpr mice contained ~63% CD3⁺ cells of which ~46% were $\alpha\beta$ TCR⁺ and ~42% were $\gamma\delta$ TCR⁺. Interestingly, however, in old lpr mice the CD3⁺ T cells increased to ~86% and majority of these (~81%) were $\alpha\beta$ TCR⁺ and only ~3% were $\gamma\delta$ TCR⁺. Young lpr DN thymocytes demonstrated strong proliferative response to stimulation with PMA + calcium ionophore, PMA + IL-2, and to immobilized mAb directed against TCRs, (CD3, $\alpha\beta$ and $\gamma\delta$), comparable to the responses obtained with similar cells from MRL +/+ mice. In contrast, old lpr DN thymocytes demonstrated marked defect (~90% decrease) in responding to the above stimuli. The present study suggests that in MRL-lpr/lpr mice with age, DN $\alpha\beta$ -TCR⁺ cells are produced in large numbers majority of which express CD45R and respond poorly to mitogenic stimuli or when activated through the TCR. It is likely that these cells give rise to the abnormal DN T cells found in large numbers in the periphery of old mice. (Supported by NIH grants CA45009 and CA45010).

NOVEL PROTOCOL FOR SATURATION MUTAGENESIS OF CLONED VIRAL GENES. P.C. Kilian and D. L. Russell, Dept. of Biol., Washington and Lee Univ. Lexington, Va. 24450. The most effective method to protect an organism against infection by a virus is immunization with an active attenuated vaccine strain of the virus. It is imperative that a number of attenuating mutations be present in the vaccine strain to prevent reversion to virulence within the vaccinated host. The advent of molecular biology has made the construction of genetically engineered vaccine strains with known attenuating mutations possible, however these mutations must first be selected from the wild-type population or created by mutagenesis and characterized individually and in combination. This presentation concerns a novel methodology which is currently being developed for creating a library of mutants in a viral gene known to be involved in early events of viral infection. This work is Ms. Kilian's Undergraduate Honors Thesis and has been supported by funds from Washington and Lee University.

PROBING INTERACTIONS BETWEEN RNA POLYMERASE AND A PHAGE-ENCODED TRANSCRIPTIONAL ACTIVATOR USING SITE-DIRECTED MUTAGENESIS. Rodney A. King and Gail E. Christie, Dept. of Microbiology and Immunology, Va. Commonwealth Univ., Richmond, Va, 23298-0678. The bacteriophage P2 *ogr* gene encodes a 72 amino acid, zinc-binding protein which is required for activation of P2 late gene transcription. P2 late transcription is blocked by the host mutation *rpoA109*, which is a leucine to histidine substitution in the alpha subunit of DNA-dependent RNA polymerase. Spontaneous P2 mutants that overcome this block have been isolated and are the result of a tyrosine to cysteine amino acid substitution at amino acid 42 in the Ogr protein. The compensatory nature of this mutation suggests a direct interaction between Ogr and RNA polymerase. Using suppression of an *ogr* amber mutation and site-directed oligonucleotide mutagenesis, we have studied the effect of all possible amino acid substitutions at this position in both wild type (*rpoA+*) and mutant (*rpoA109*) strains of *E. coli*. Our results indicate that substitution of a charged amino acid results in a nonfunctional Ogr protein, regardless of the strain background. Multiple polar and non-polar substitutions are functional to varying degrees in the *rpoA+* strain. In sharp contrast, only substitutions of cysteine, alanine and glycine will support growth of P2 in the *rpoA109* background. These results support a direct interaction between Ogr and the host RNA polymerase and suggest that the inability of wild-type Ogr to function in an *rpoA109* strain is due to steric constraints.

CHARACTERIZATION OF DEFECTIVE ANTIGEN PROCESSING BY GENETIC COMPLEMENTATION. B.J. Merkel and K.L. McCoy, Dept. of Micro., Va. Commonwealth Univ., Richmond, VA 23298. Antigen processing, occurring in antigen-presenting cells, is the mechanism by which immunogenic peptides are generated from native proteins within intracellular compartments. The regulation and mechanism of antigen processing are largely uncharacterized. WAB4, a Chinese hamster ovary cell line transfected with I-A^d MHC class II genes, processed native antigens ineffectively and was unable to stimulate 3D054.8, an I-A^d-restricted, ovalbumin-specific T_h cell hybridoma. To understand the mechanism responsible for the defect, we examined whether normal antigen processing in these cells could be restored by genetic complementation. WAB4 was fused by polyethylene glycol with L cells, a fibroblast transfected with I-E^k MHC class II genes, known to be a competent antigen-presenting cell. Two distinct hybrids, WALC and LLC were isolated by a double drug selection protocol. LLC predominantly expressed I-E^k MHC class II gene products and stimulated 2B4, an I-E^k-restricted, pigeon cytochrome c-specific T_h cell hybridoma. WALC expressed both I-A^d and I-E^k MHC class II molecules. In contrast to WAB4, WALC was very effective in activating an antigen response by 3D054.8 suggesting that the normal genes contributed by the L cells, corrected the recessive antigen-processing defect. Finally, the identification of the gene(s) responsible for complementing the antigen processing defect would lead to a better understanding of the regulation of the mechanism. (Supported by Thomas F. Jeffress and Kate Miller Jeffress Memorial Trust J-173.)

INDETERMINATE HIV-1 WESTERN BLOT RESULTS AND THEIR CLINICAL SIGNIFICANCE. R. Rodriguez-Bayona, M.R. Escobar and C.W. Moncre, Dept. of Pathology, Box 106, MCV Station, MCV-VCU, Richmond, VA 23298. This is a retrospective study to correlate Abbott ELISA (repeat positive) and Western Blot (WB, Bio Rad) antibody test results with clinical history and risk group in 671 patients suspected of having HIV-1 infection whose sera were collected from March, 1988 to December, 1990. The WB results of this study population were: 623 (92.8%) reactive; 36 (5.4%) nonreactive; and, 12 (1.8%) indeterminant (IND). None of the 12 WB-IND had clinical findings consistent with HIV-1 infection, whereas the 19 WB reactive (WB-R) used as controls had a clinical history compatible with HIV-1 infection. Virtually all the WB-IND had ELISA O.D. values close to the cut-off. On the other hand, there was a positive correlation between the O.D. values (> 2.0) and the number of bands seen in the WB. None of the 12 WB-IND admitted to being homosexual or bisexual; however, 7 were intravenous drug users (IVDUs), 4 were transplant recipients, 5 had received transfusion(s) and 4 were on hemodialysis. None of the 19 WB-R were transplant recipients, but 11 were IVDUs, 7 were homosexual or bisexual, 1 was a hemophiliac, 1 was a female who had been exposed to her HIV-1 positive heterosexual partner, and 1 was an infant whose parents were both HIV-1 positive. Of the 19 WB-R, 2 had received transfusion(s) and 2 were on hemodialysis. It is suggested that close clinical consultation and follow-up are essential for all patients with WB-IND.

INHIBITION OF AUTOCRINE GROWTH AND TUMORIGENICITY INDUCED BY A T CELL CLONE *IN VIVO* USING MONOCLONAL ANTIBODIES AGAINST IL-2 AND IL-2R. Aruna Seth, K. Manickasundari, Mitzi Nagarkatti and Prakash S. Nagarkatti. Department of Biology, Virginia Polytechnic Inst. & State Univ., Blacksburg, Va 24061.

The development of tumors requires the simultaneous presence of a number of molecular perturbations and autocrine growth factor production is one such factor. We have recently isolated a CD4⁺ autoreactive T cell clone (designated AutoD1.T) which was found to grow independent of exogenous T cell growth factors or stimulation through the TCR. The autocrine growth of this T cell clone, *in vitro*, was inhibited by the presence of anti-IL-2 or anti-IL-2R mAb but not anti-IL-4 mAb. These data suggested that the *in vitro* transformation of the T cell clone resulted from unregulated endogenous secretion of and responsiveness to IL-2. The AutoD1.T clone could also induce tumors when injected into nude mice. Inasmuch as it is not proven that autocrine growth factors are the only limiting factors for the neoplastic transformation *in vivo*, we next addressed whether the tumorigenicity of AutoD1.T could be inhibited by using mAb against T cell growth factors. Interestingly, mAb against IL-2 and IL-2R but not against IL-4, completely inhibited the tumorigenicity of AutoD1.T *in vivo*. Also, cyclosporin A when used alone or in combination with anti-IL-2 mAb, inhibited the tumor growth significantly. Together, our data suggest that T cell transformation and tumorigenicity *in vivo* can result exclusively from autocrine growth factor production and such tumors can be effectively treated by antibodies against the growth factors or their receptors. (Supported in part by NIH grants CA45009 and CA45010 and a fellowship award from the American Foundation for Aging Research)

REGULATION OF GLYCOGEN PHOSPHORYLASE GENES IN *Dictyostelium discoideum*. Joseph F. Sucic, S. Luo*, P.V. Rogers*, O. Selmin*, Y. Yin*, R.B. Peery*, K.P. Lindgren*, and C.L. Rutherford*, Va. Polytechnic Inst. and State Univ., Blacksburg, Va. 24061. The cellular slime mold, *Dictyostelium discoideum*, undergoes a well documented developmental cycle during which cellular differentiation occurs. A crucial event in cellular differentiation in *Dictyostelium* is glycogen degradation, which provides glucose precursors used to synthesize components of differentiated cells. Glycogen degradation is catalyzed by glycogen phosphorylase, and we have identified two developmentally regulated glycogen phosphorylase activities in *Dictyostelium*; these activities are associated with two distinct proteins which are the products of separate but related genes. Sequence comparisons showed that these genes are similar to glycogen phosphorylase genes of other organisms. Northern blots revealed that the two glycogen phosphorylase genes are developmentally regulated. The regulation of both genes is mediated by cAMP, but each gene appears to be regulated through a different intracellular molecular mechanism.

MICROBIOLOGICAL AND SPECTROPHOTOMETRIC DETECTION OF ENTERIC PATHOGENS FROM POULTRY RINSES. Helen C. Sutton, Dept. of Food Science, & Germille Colmano, Dept. of Biomedical Sciences, VMRCVM, VPI & SU, Blacksburg VA, 24060-0442. Differences between ultrafiltrates of sterile media and of media with bacterial cultures were detectable in recorded spectrophotometric scans (650nm-190nm). The bacterial growth in the culture media, by modifying the content of the original nutrients by uptake and waste production, gave noticeable differences not only in the 24 hr cultures, but also in the zero time cultures. These differences were large enough to differentiate *S. typhimurium* from *S. arizona*, *E. coli* and a combination of all three, allowing for their detection in samples immediately after their collection time (time zero). It should be noticed that this detection was possible not only on the bacterial cultures at time zero, but also in the water rinses of raw chicken breast, and in the cultures of the rinses in broth, leading us to believe that we are offering the food industry a novel, rapid and simple way to test for the differentiation of human enteric pathogenic bacteria in poultry and other food products.

NA-CA EXCHANGE, CA-ATPASE, AND ALTERED CALCIUM HOMEOSTASIS IN LENS FROM SELENITE-TREATED RATS. Zhaiqi Wang, J. L. Hess, and G. E. Bunce, Dept. of Biochem. & Nutr., Virginia Polytechnic Inst. & State Univ., Blacksburg, VA 24061-0308. Subcutaneous injection of 30 nmol Na₂SeO₃/g body wt into 10-14-day old rats leads to altered Ca homeostasis after 36 hr. Bilateral nuclear cataract appears within 72-96 hr and is accompanied by a 3-5 fold increase in lens total Ca. Incubation of lenses from selenite-injected rats in medium containing 15 mM CaCl₂ has shown that, within 24-36 hr post-injection, passive permeability of Ca is doubled and active Ca transport is reduced to 50% compared to age-matched control lenses. Both of these effects can be reversed by the sulfhydryl reductant, DTT (2-5 mM). Experiments with Na gradients indicated that Na/Ca exchange participates in lens Ca homeostasis. (Supported by NIH R01EY06123 and Pratt Nutrition Program, VPI & SU).

Psychology

THE EFFECT OF A BIASED QUESTIONNAIRE USING ACQUIESCENCE AND MARKED MODIFIERS ON POLITICAL ATTITUDES. Douglas C. Bates, Dept. of Psyc., Old Dominion Univ., Norfolk, Va. 23529. The ability to influence political attitudes by using biased questionnaires was investigated. It was thought that subjects' answers to factual questions about a news story could be biased through the use of acquiescence (expecting a positive response style), and marked-unmarked modifiers (i.e. "few" vs. "many"). Afterwards, it was expected that subjects' attitudes toward the domain in the news story (Israeli-Palestinian issues) would be swayed in the direction of the biased questionnaires. Eighty-one subjects were randomly assigned to four groups of about 20 each. All filled out Israeli-Palestinian attitude surveys. The control group did nothing else; another group watched the news story first, the other two groups watched the news story and answered biased questionnaires (either positive or negative) before answering the attitude surveys. No significant differences in attitude were found, although the survey was found to be both reliable and valid. It is assumed that the concurrent United Nations war against Iraq solidified subjects' attitudes toward the Middle East, thereby wiping out the effect of biasing questions.

SEARCHING FOR LOVE: A COMPARISON OF MALE AD PLACERS FROM TWO METROPOLITAN AREAS. Chet H. Fischer, Department of Psychology, Radford Univ., Radford, Va. 24142. A central concern for many of the sixty-five million adult singles is how to unite with other appropriate and compatible singles. Fischer (1990) randomly sampled male and female ad placers who advertised in Washington, D.C. and Roanoke, VA metropolitan magazines. The results indicated that women advertisers tended to be quite similar with reference to income, education, age employment and assertiveness. Male advertisers, on the other hand, tended to be significantly dissimilar. The present study examined the important differences between male advertisers from these two areas. The males from the smaller metropolitan area tended to be less educated, have substantially lower incomes, employed in fewer professional occupations, have had fewer marriages and received a larger number of replies from age discrepant women. The males from the larger metropolitan area were considerably more satisfied with advertising than were their small town counterparts.

DUI-PREVENTION RESEARCH AT PARTIES: SOME PRACTICAL CONSIDERATIONS AND IMPLICATIONS. K.E. Glindemann, E.S.Geller, & C.M. Coleman, Dept. of Psyc., Va. Tech., Blacksburg, Va. 24061. The Center for Applied Behavior Systems has conducted a series of alcohol consumption studies at university parties over the past ten years, and in so doing has developed methodologies for accomplishing objective field research in such naturalistic settings (e.g., Geller & Kalsher, 1990; Geller, Kalsher, & Clarke, in press; Geller, Russ, & Altomari, 1986; Glindemann, Evans, & Geller, 1989; Russ & Geller, 1988). Much of this research was designed to determine situational determinants of excessive party drinking, whereas other research was designed to determine individuals' accuracy at estimating parties' intoxication levels through behavioral testing and observation. This paper discusses the methodology we have developed for this type of research, strategies for collecting relevant data in the field, and implications for the prevention of DUI (driving under the influence of alcohol).

A LONGITUDINAL STUDY OF THE EFFECTS OF NAVY DEPLOYMENT ON THE MARITAL SATISFACTION OF NAVY WIVES. Brenda G. Gooch, Marci Harris*, Michelle Kelley*, Old Dominion Univ., Dept. of Psychology, Norfolk, VA 32529. The purpose of this research was to assess the effects of Navy deployment on the perceived marital satisfaction of military wives. Fifty-one women whose husbands were deployed to the Persian Gulf completed the Index of Marital Satisfaction (IMS; Hudson, (1985) at pre-deployment (one month prior to departure), and mid-deployment (12-16 weeks after the husband's departure). Results of a 2 (husband's rank) X 2 (employment) X 2 (phase of deployment) X 2 (wife's age) showed a 3-way interaction, $F(1,44) = 6.18$, $p < .05$. Although marital satisfaction increased slightly for enlisted wives from pre-deployment to mid-deployment regardless of employment, and for officers' wives who worked, marital satisfaction declined substantially from pre-deployment to mid-deployment for officers' wives who were not employed. Thus, it appears that officers' wives that are not working (and who are presumably educated and employable), may be particularly vulnerable to marital stress in the husband's absence.

MMPI TRENDS IN AN ADOLESCENT SEX OFFENDER POPULATION. Dennis W. Goodwin, Dept. of Psych., Old Dominion Univ., Norfolk, Va. 23508, John A. Hunter Jr. Ph.D., Pines Treatment Center, Behavioral Studies Program, Portsmouth, Va., & Robin J. Lewis Ph.D., Old Dominion Univ., Norfolk, Va. 23508. Sex offenders as a population are considered to be heterogeneous. A need exists to find more homogeneous subtypes. Although there is a plethora of research with adult sex offenders, there is a dearth of literature dealing with adolescent offenders. The current study looks at the utility of the MMPI to differentiate different subtypes of adolescent offenders. Subject consist of 60 adolescent male sex offenders divided into groups based on their own history of victimization and whether their own offence was incestuous or non-incestuous. Results are compared to the current adult literature as to the ability of the MMPI to differentiate subtypes.

EVALUATION OF OCCUPATIONAL SAFETY WORKSHOPS; A NEED FOR TOP-MANAGEMENT SUPPORT. Melody Griffin-Hamilton, Gisele Wright* and E. Scott Geller, Dept. of Psychology, VPI & SU, Blacksburg, VA 24060. The purpose of this study was the evaluation of safety behavior training workshops given by trained professionals in a corporate setting. Five hundred and seventy four wage employees of the plant participated in the sessions. The sessions consisted of slide presentations, work booklets and lectures. At the end of each session the employees were asked to complete a questionnaire evaluating the strengths and weaknesses of the sessions. The questionnaire was completed by 60% of the 574 employees that participated in the sessions. Forty-four percent of the employees responded that their own attitude toward plant safety, positive behavior change and self-esteem was affected negatively by management's lack of support. The results of this study suggest that for corporations to have employees concerned about work safety in the plant, there first must be support and involvement from management.

AN EVALUATION OF REACTION TIME TESTS APPLICABLE IN A PARTY SETTING FOR ASSESSING BAC. R.D. Halsey, D.M. Maglietta, & C.T. Buchholz, Dept. of Psyc., Va. Tech., Blacksburg, Va. 24061. This study tested possible procedures for assessing intoxication in a university drinking-age population. Partiers signed an informed consent sheet and were assigned a subject number as they entered a designated party where alcohol was present. During the course of the evening, a researcher approached a potential subject and asked them to enter a separate room to participate in three tests. These tests were designed to test the subjects psychomotor performance and were presented to the subjects in a counter-balanced fashion. After completing the tasks, the subjects were escorted to another area where their blood alcohol concentration (BAC) was determined by a breathalyzer. BAC readings were later correlated with performance on the three psychomotor tasks. It was expected that performance on the tasks would decrease as subjects' levels of intoxication increased. Results of the study, as well as implications of the findings, are discussed.

CLASSROOM ARRANGEMENT AND INSTRUCTOR RATING PREDICTION. J. Richard Holcomb, & Raymond Kirby, Dept. of Psychology, Old Dominion University, Norfolk, Va. 23501. Predictions of instructor ratings were studied with reference to classroom arrangements using questionnaire responses to pictures of different classroom arrangements. Arrangements were varied for student-desk placement and instructor desk type. It was hypothesized that circular student-desk arrangements and informal instructor-desk type would be related to higher ratings of instructor openness, fairness, and effectiveness. 112 undergraduate students at Old Dominion Univ. participated. Analyses of variance by condition indicated significant main effects for student-desk arrangement and instructor-desk type on each measure except for instructor-desk type and effectiveness. Post-hoc analyses indicated that means for each condition were significantly more positive as student-desk arrangement became more circular and instructor-desk type became more informal. These results support previous research on student-desk arrangement. Further research is suggested on instructor-desk type and the benefits of different classroom environments on different subject matter.

MOTIVATIONAL TECHNIQUES FOR RECYCLING BEHAVIORS: GROUP DISCUSSION vs. GROUP COMMITMENT. Shawn E. Johnson & Lynette A. Barn, Dept. of Psychology, Virginia Polytechnic Inst. and State Univ., Blacksburg, Va. 24061. The purpose of this study was to motivate recycling behaviors in male college dorm residents. Past studies have concluded that commitment techniques, where individuals agree to perform specific target responses, can be used in modifying behaviors. A three-floor male dorm, consisting of 327 subjects, was sampled. The first and third floors served as experimental groups while the second floor served as the control group. Two intervention techniques were administered. The first intervention consisted of group discussions, which were facilitated in an effort to promote an awareness on the benefits of recycling. During the second intervention, dormitory residents were encouraged to sign pledge cards of commitment to recycle aluminum for two weeks. Results of this study indicated a significant increase in recycling in the experimental groups, but also in the control group. The amount of recyclables collected after the interventions decreased, but remained significantly higher than the amount collected during the baseline phase. The ease and convenience with which these commitment and group discussion procedures were disseminated suggested economical as well as effective methods of modifying desired behaviors in recycling.

COMPARISON OF SURVEYS OF TWO CORPORATE-BASED RECYCLING SITES. Sharon K. Kollas, *Kathy Rumrill, *Dan Stetler, Dept. of Psych., VA Polytechnic and State Univ., Blacksburg, VA 24060. Two companies in rural Southwest Virginia participated in a program to increase recycling by their employees (n=32, n=300). Recycling sites were set up at each of these companies for the employees to bring their recyclables from home. As the second intervention of an ongoing intervention program, a survey was administered to employees as they were leaving work. The survey consisted of eight questions that inquired about the employees knowledge and opinions of the recycling program. The surveys were analyzed as to determine the correlation between the employees' awareness of the implemented programs and their rates of participation.

ASSESSING INTOXICATION IN THE FIELD: USE OF SIGNATURES TO ESTIMATE PARTIERS' BACS. S.E. Little, J.M. Satz, & K.E. Glindemann, Dept. of Psys., Va. Tech., Blacksburg, Va. 24061. The use of writing samples as indicies of alcohol impairment was explored. A pilot study performed by the research team suggested that handwriting can, in fact, serve as a valid index of alcohol impairment. In this study, students at a campus fraternity party (N=72) wrote a sentence before and after consuming alcohol (in beer and mixed drinks). In the exit condition (i.e., after consuming alcohol), one half of the subjects were informed that the samples of their handwriting would be analyzed in an attempt to determine their level of impairment (i.e., experimental condition), and the remaining half of the subjects were left uninformed as to this purpose (i.e., control condition). When leaving the party, students' blood alcohol concentration (BAC) was assessed with a breathalyzer. Later, undergraduate and graduate students (N=25) attempted to discriminate between pre- and post-party handwriting samples, and then classified the presumed post-party samples along a continuous scale of BAC level. Results of this study, along with relevant implications of the research, are discussed.

EFFECTS OF LESIONING THE ENTORHINAL CORTEX AND VENTRAL SUBICULUM ON LATENT INHIBITION. Gregory L. Lyford and Leonard E. Jarrard, Dept. of Psychology, Washington and Lee University. Latent inhibition is retarded learning about a stimulus after that stimulus has been preexposed in a nonreinforced context. Conventional lesions of the hippocampus are known to increase learning to the preexposed stimulus. In the present study, the entorhinal cortex and ventral subiculum were aspirated in rats. Using a within-subjects conditioned suppression procedure, we tested these animals for latent inhibition. Contrary to our expectations we found that the lesioned animals did not differ from controls as both groups demonstrated a robust latent inhibition effect. Further study of the hippocampal formation is necessary to discover the crucial neural substrates of latent inhibition.

SPATIAL MEMORY IN THE YOUNG AND THE ELDERLY. Andrew B. Manson, Dept. of Psyc., Washington and Lee Univ., Lexington, VA 24450. College undergraduates (Mean age = 19.5 years) and elderly faculty or former faculty (Mean age = 66.2 years) viewed an apparently three-dimensional table top displayed on a computer. The display included 1 or 4 landmarks and a target object. After viewing the display for 5 sec, the target was moved and the subjects had to replace it in its original position. The landmarks were systematically moved either to the left or the right of the observer. Errors in relocating the target followed the movement of the landmarks, and relocation errors tended to be greater when there were 4 landmarks than when there was 1. These results are consistent with a vector sum model of spatial memory. The two age groups did not differ in their ability to relocate the target accurately, and both age groups reacted similarly to movement of the landmarks. Since healthy older adults performed well, the task may be a valuable one for assessing spatial, non-verbal memory in demented elderly people.

EFFECTS OF ASTHMA ON THE SOCIAL DEVELOPMENT OF CHILDREN. Chelley A. Merrell & Michelle L. Kelley*, Dept. of Psychology, Old Dominion University, Norfolk, Va. 23508. The purpose of the present research was to examine the impact of asthma on children's (6 to 12-years old) social development and behavior. Mothers of severe asthmatics (i.e., steroid-dependent), moderate asthmatics (i.e., non-steroid-dependent), and non-asthmatic siblings were administered the Vineland Adaptive Behavior Scale-Survey Form (Vineland: Sparrow, Balla, & Cicchetti, 1984) and the Child Behavior Checklist (CBCL: Achenbach & Edelbrock, 1986). Three areas of social development were assessed by the Vineland: Communication, Daily Living Skills, and Socialization. The following dimensions of the CBCL were assessed: Internalizing, Externalizing, Depressed, Aggressive, Hyperactive, Obsessive, and Somatic Complaints. It is hypothesized that children with severe asthma will demonstrate lower levels of social development and exhibit higher levels of negative child behaviors than either the moderate asthmatics or non-asthmatic siblings. Findings will be discussed in terms of the impact of chronic illness on the child and family functioning. (Supported by the Dept. of Pediatrics, Children's Hospital of The King's Daughters, Norfolk, Va.)

ON THE NEURAL BASIS OF THE CONDITIONED EMOTIONAL RESPONSE: EFFECTS OF IBOTENATE LESIONS OF THE HIPPOCAMPUS. Margaret G. Mckernan, Dept. of Psych., Washington and Lee Univ., Terry L. Davidson, Dept. of Psych., Purdue Univ., Leonard E. Jarrard, Dept. of Psych., Washington and Lee Univ., Lexington, VA 24450. Rats with selective ibotenate lesions of the hippocampus were trained to bar-press on a variable interval schedule of reinforcement. When a baseline level of responding was achieved, the rats underwent fear conditioning, pairing a steady light (CS) with a .5s shock (UCS) to elicit a "freezing" response. The strength of this conditioned emotional response was then measured by looking at suppression of bar-pressing during CS-presentation. While hippocampus-lesioned animals displayed an overall decreased tendency to freeze relative to controls during fear conditioning, they did not differ significantly from controls in bar-pressing suppression ratios, suggesting that the hippocampus may not be essential for the acquisition of conditioned emotional response.

INTERNATIONALIZING PSYCHOLOGY CURRICULA: LESSONS AND MATERIALS FOR EASTERN EUROPE AND THE SOVIET UNION. James P. O'Brien, Tidewater Cmnty. Col., Virginia Beach, VA 23456. A recent state commission report "The University in the 21st Century" emphasized the need for preparing our students to survive and prosper in a world of increasing national interdependence. This is to be accomplished by faculty in all curricula providing a global perspective. Instructional modules and related materials prepared for a faculty seminar are discussed; in particular, behavior control, Ivan Pavlov, and ergonomics. They are designed to provide the student with the social, cultural, geographical, and historical context in which major contributions to the field have been made or different approaches have been used. Topics and individuals already covered in psychology courses (e.g., Wilhelm Wundt, gestalt psychology, propaganda, social power, etc. in addition to the above) can easily serve as vehicles to familiarize students with political, economic, social and other factors which provide a context for psychological research and theory developed overseas.

AUTOMATIC PROCESSING AN AUDITORY ORIENTATION: AN AUDITORY STROOP EFFECT. Jason L. Parker, Dept. of Psyc., Old Dominion Univ., Norfolk, Va. 23508, & W. Lichty, Dept. of Psyc., Old Dominion Univ., Norfolk, Va. 23508. Research has shown that cognitive performance is effected by word, color and word-color incongruities. Current research suggests that a similar effect may exist with words presented aurally. This study proposes a method in which the Stroop Color Word Test may be transferred into an auditory form. The subjects for the experiment were 12 undergraduate college students from Old Dominion Univ.. The Auditory-Stroop task asked subjects to respond to right and left stimulus presentations played into stimulus congruent and incongruent ears. An Analysis of Variance was calculated. The results of the experiment were compared to those of the Color Word Stroop and a 2 color version of the Stroop.

MOTIVATING RECYCLING BEHAVIOR: A COMPARISON OF MOTIVATIONAL TECHNIQUES. Kim Randall, *Gisele Wright, Melody Griffin-Hamilton, & Sharon Kollas, Center for Applied Behavior Systems, Psychology Dept., VA Polytechnic Institute and State Univ., Blacksburg, VA. The need for recycling and other proenvironmental behaviors has been a topic of increasing concern in both the scientific and popular press. This research examined a novel format for collection of household recyclable material, while also testing a motivational package designed from a taxonomy of behavior change techniques. The employees at two industrial sites (n=32, n=300) were encouraged to bring their recyclable materials from home to the work site. Posters, feedback, a group meeting, and questionnaires were the techniques used to increase participation in the program. Analysis of dependent measures indicated the relative effectiveness of the separate techniques, as well as the combination of the techniques, and social validity (i.e., the satisfaction of the employees as consumers).

VEHICLE SAFETY BELTS: CAN AN AUTOMATIC SYSTEM BE DETRIMENTAL?

Kim Randall, * Gisele Wright, and Melody Griffin-Hamilton; Dept. of Psychology, VPI&SU, Blacksburg, Va. 24061-0436. Automatic shoulder belts are very popular in the automobile industry. In addition to the automatic shoulder belt, most cars have a manual lap belt. In automobile collisions, the automatic shoulder belt decreases the impact between the driver and the car's dashboard. A number of automobile deaths result from the driver being thrown from the vehicle. For this reason it is important that lap belts are used to restrain the driver from being tossed during a vehicle collision. This study observed the influence of automatic shoulder belts on the use of manual lap belts. Subjects (n=60) were surveyed on their past use of manual safety belts compared to their present use of the manual lap belt (in cars with automatic shoulder belts) and their feelings regarding use of both the automatic shoulder belt and the manual lap belt (i.e., Are you safe with use of the shoulder belt alone). Results show that for 37% the automatic shoulder belt does not influence lap belt use, for 38% the automatic shoulder belt increases the use of the lap belt, for 18% there was a decrease, and 7% did not know.

ABOUT FACES: A STUDY IN ELECTRO-DERMAL ACTIVITY (EDA) AND THE PROCESSING OF FAMILIAR AND DISTINCTIVE FACES. Don Shearer, Jr. and Peter Mikulka*, Dept. of Psych., Old Dominion Univ., Norfolk, Va. 23405. This study focuses on two dimensions of the facial recognition process - the familiarity and distinctiveness of faces. One hundred and three black and white slides of various faces gathered from current periodicals were made into 35mm slides. These stimuli were then viewed by 50 undergraduate student subjects to rate verbally familiarity on a 1-7 Likert scale, and were also asked to name the faces if possible. Forty-eight different subjects were asked to rate verbally the same stimuli for distinctiveness on a 1-7 Likert scale. Forty stimuli were selected from the original 103. These 40 stimuli represented both high and low ratings on the two dimensions and were shown to an additional 25 subjects. Using EDA measures and verbal ratings of a feeling of knowing or identification of the face, data were collected. A GLM analysis of these data showed a significant main effect for familiarity which indicated that larger EDA amplitude occurred to the more familiar faces. While administering the trials, a "double arousal" pattern termed the "W" effect was uncovered. Familiarity had a significant effect on this phenomenon as well.

EFFECTS OF MOVING LANDMARKS ON SPATIAL MEMORY. Heather A. Turner, Anne Culley, David G. Elmes, Courtney Penn, & Joseph B. Thompson, Dept. of Psyc., Washington and Lee Univ., Lexington, VA 24450. On a computer display, college students viewed an apparently three-dimensional table top. The display included 1, 2, or 4 landmarks and a target object. After viewing a display for 5 sec, the target was moved and the subjects had to replace it in its original position. Landmarks were systematically moved either toward or away from the observer. Errors in relocation were unrelated to the number of landmarks. However, the magnitude and direction of the error followed the displacement of the landmarks. The results are consistent with a vector sum model of spatial localization that accounts for characteristics of animal spatial memory.

EFFECTS OF ENTORRHINAL CORTEX LESION ON RETENTION IN NON-MATCHING TO SAMPLE TASK IN RATS. W. Kelly Vandever, Scott E. Miller, Greg L. Lyford, and Leonard E. Jarrard, Dept. of Psych., Washington and Lee Univ., Lexington, VA 24450. In the present study, we used rats and a non-matching-to-sample task (NMTS) in order to study the rule of the entorhinal cortex (EC) in memory. In previous experiments, lesioning of the hippocampus has led to disruption of spatial acquisition and retention in rats but not in acquisition of a non-spatial test of working memory-delayed non-matching-to-sample (DNMTS). In our experiment, rats were trained to select the novel of two stimuli (NMTS task) in a Y-arm maze. Once attaining criterion level (80%) for the acquisition task, EC lesions were performed on half of the rats followed by post-operation testing. There was no significant difference in performance between the lesioned and control rats, thus suggesting that the cortical inputs to the hippocampus via EC do not play an important role in this type of learning.

USING PHYSICAL CHARACTERISTICS AS A PREDICTOR OF NEGATIVE DRIVING OUTCOMES. John A. Wangler, Bryan E. Porter, E.Scott Geller, Dept. of Psychology, and R.B. Frary*, Learning Resources Center, Va. Polytechnic Inst. and State Univ., Blacksburg, VA 24061. Automobile safety involves many complex factors. In particular, risky driving behavior may be correlated with an individual's physical traits and driving experience. This study examined four main independent variables (handedness, visual acuity, number of speeding tickets accumulated, and years of driving experience) and their correlation with reported automobile accidents. It is plausible that any or all of these variables may be used as a predictor of future automobile accidents. A questionnaire was devised asking college students about physical traits (i.e. left-handedness), driving speeds, and driving records. Subjects consisted of undergraduates enrolled in introductory Psychology courses, as well as a cross sample of other college-age students enrolled in other psychology courses. A four-variable multiple regression procedure was performed. The number of driving tickets that one has accumulated and one's visual acuity were shown to be variables which allow us to significantly predict an individual's number of automobile accidents. Implications of this study are discussed.

Statistics

LOGISTIC REGRESSION APPLIED TO TREE MORTALITY PREDICTION. Olga B. Avila & Harold E. Burkhart, Dept. of Forestry, Va. Polytechnic Inst. & State Univ., Blacksburg, VA 24061-0324. The probability of mortality for an individual tree with certain characteristics growing under certain conditions was modeled. A particular algorithm SCREEN was used to find the best set of predictor variables. This algorithm was specially created to be used when the dependent variable can take only two values like in this binary case (dead or alive tree). The logistic model with different independent variables, which were found to be significant through the SCREEN algorithm, was fitted to the data. The appropriateness of the logistic model obtained using as independent variables individual tree crown ratio, ratio of tree total height to the average height of dominant and codominant trees, and competition index was studied. The value of the model deviance did not reject the null hypothesis that the logistic was an appropriate model. The analysis was repeated when substituting the ratio of the stand quadratic mean diameter to the individual tree diameter at breast height for the competition index. Similar results were obtained. Validation of the models showed no major improvements of the logistic model when including more than three independent variables.

BAHADUR EFFICIENCIES FOR CONTAMINATED NORMAL DISTRIBUTION.

Narasinga Rao Chaganty and Akhil K. Vaish, Dept. of Mathematics and Statistics, Old Dominion University, Norfolk, Va. 23529. In this paper we obtain the Bahadur slopes of the common test statistics used for testing a hypothesis for the location parameter of a mixture of two normal distributions. We use these results to study the robust properties of the test statistics using Bahadur efficiency, which is defined as the ratio of Bahadur slopes, as a criteria for normal populations in the presence of contamination.

METHODS FOR MEASUREMENT OF GEOGRAPHICAL VARIATIONS FOR EVALUATING THE QUALITY OF HEALTH CARE. R. Clifton Bailey, Health Standards and Quality Bureau, ME 2-D-2, 6325 Security Boulevard, Baltimore, MD 21207(BITNET: R3B@NIHCU)

The Health Standards and Quality Bureau (HSQB) is charged with the assurance of the appropriateness and effectiveness of the medical care provided to Medicare beneficiaries. The presentation will focus on methods and models for analyzing the mortality outcome for the health care delivered to Medicare Beneficiaries and population based mortality and hospital use. The presentation will describe a general approach for this type of assessment. Specific applications include a modified Makeham survival model in which concomitant variables are used to evaluate the long- and short-term risks, and a modified zero-class Poisson regression. The points illustrated by the examples can be applied broadly in the evaluation of the quality of health care.

A ROBUST F TEST IN MULTIPLE REGRESSION. Jeffrey B. Birch, Dept. of Stat., Va. Tech., Blacksburg, Va. 24061, & David B. Agard*, N. Ky. Univ. Outliers are observations of the response variable not consistent with any pattern or trend expressed by the remainder of response data. It is well known that outliers in a multiple linear regression (MLR) analysis can distort the estimates of the unknown parameters. In addition, inferences made on parameters can also be adversely affected by outliers. In this paper, we study the impact of several types of outliers on the classical inferential techniques used in MLR. We also present several inferential procedures, introduced in recent literature, designed to be robust against outliers and propose two new alternative robust methods, the F-tests based on robust weights. The power of these robust procedures, along with the power of the classical methods, will then be compared in a simulation study.

MULTIVARIATE EXPONENTIALLY WEIGHTED MOVING AVERAGE CONTROL CHARTS FOR THE MEAN VECTOR AND VARIANCE-COVARIANCE MATRIX WITH VARIABLE SAMPLING INTERVALS.

Gyo-Young Cho* and Marion R. Reynolds, Jr., Dept. of Stat., Va. Polytechnic Inst. and State Univ., Blacksburg, VA 24061. When using control charts to monitor a process it is frequently necessary to simultaneously monitor more than one parameter of the process. Multivariate exponentially weighted moving average (EWMA) control charts for simultaneously monitoring the mean vector and variance-covariance matrix of a process with a multivariate normal distribution are investigated. A variable sampling interval (VSI) feature is considered in these charts. For multivariate EWMA control charts for the mean vector and variance-covariance matrix, three procedures which depend on how past sample information is used are presented. The first multivariate EWMA procedure reduces each multivariate observation to a scalar and then forms a EWMA of the scalars. The second multivariate EWMA procedure accumulates past sample information for each parameter and then forms a univariate EWMA statistic from the multivariate accumulations. The third procedure uses p separate EWMA charts for each parameter. These three control procedures are compared on the basis of their average time to signal (ATS) performance.

DISCRIMINANT ANALYSIS OF EXPERIMENTAL DATA FROM SPECTRAL DATA OF BLOOD SERUM FROM SELENIUM DEFICIENT AND PREGNANT HEIFERS. Lyle Evans & Germille Colmano, Dept. of Biomedical Sciences, VMRCVM, VPI & SU, Blacksburg VA, 24061-0442. Discriminant Analysis to identify pregnant and Se deficient heifers was based on UV-VIS spectrophotometry of their blood serum using absorbance values from 190nm to 650nm (a challenge to statistical analysis as there are many more variables than observations and the variables are correlated). A small number of principal components were used to effect a reduction in dimensionality. Discriminant analysis was performed using those principal components that exhibited the best separation capability rather than those with the largest eigenvalues. In this respect our results confirm the work of Chang (1983). Discriminant analysis on a small portion of the spectra of 39 heifers (2/3 pregnant and 2/3 selenium deficient) using 20 known samples (out of 39) as training samples, performed with SAS, gave a true error of 26%. A final discriminant analysis, using the identity of all 39 samples, was performed to classify the Se+ and Se- samples. The resulting discriminant analysis gave an apparent error rate of 12.8% and gave an estimated true classification error rate of 17.9% by the method of leaving-one-out.

NECESSARY AND SUFFICIENT CONDITION FOR BOX-BEHNKEN DESIGNS. Jinnam Jo* and Klaus Hinkelmann, Dept. of Stat., Va. Polytechnic Inst., Blacksburg, Va 24061. A class of three-level incomplete factorial designs for the estimation of parameters in a second-order model was developed by Box-Behnken (1960). These designs can be constructed by combining ideas from incomplete block designs (BIBD or PBIBD) and factorial experiments, specifically 2^k factorials. We present the Box-Behnken design matrix in its general form using a PBIB(2) characterized by parameters t , r , b , k , λ_1 , λ_2 . We provide the $X'X$ matrix when we fit the second-order model. Then we consider the estimability of the mixed quadratic coefficients, and show that a necessary and sufficient condition for mixed quadratic coefficients to be estimable is that both λ_1 and λ_2 are positive. We extend the result to PBIB designs with m associate classes ($m > 2$). We also apply this result when we use fractional factorials instead of full factorials such that the two-factor interactions are not confounded with main effects.

RESPONSE SURFACE OPTIMIZATION WHEN PROCESS MEAN AND VARIANCE ARE MODELED. Yoon G Kim, Department of Statistics, Virginia Tech, Blacksburg, VA 24061 & Raymond H. Myers, Department of Statistics, Virginia Tech, Blacksburg, VA 24061. We often encounter a need to develop experimental strategies to achieve some target condition for the process mean while simultaneously minimizing its variance. G. Taguchi has emphasized the need for considering both mean and variance of the characteristic of interest. His proponents have also made significant contributions in the use of experimental design methods to achieve certain objectives - minimizing risk under a certain loss function - in a mean response while simultaneously minimizing the variance. In this article, we describe how an appropriate index and the concepts of prediction and tolerance bounds for future values at each of K separate settings of the independent variable can be used in our quest for the optimal experimental condition. These methods can be extended to the simultaneous optimization of several response variables which depend upon a number of independent variables or sets of conditions. A simple example will illustrate their usage.

MAXIMUM LIKELIHOOD ESTIMATION OF FIRST PASSAGE TIME PROBABILITIES IN A MARKOV RENEWAL PROCESS. Indira Kuruganti and Robert E. Johnson, Dept of Math Sciences, Virginia Commonwealth University, Richmond, VA 23284-2014. The National Cancer Institute has published guidelines for the preventive screening of cancer amongst asymptomatic patients. A two state Markov renewal model is proposed here to characterize the time taken for a patient to be screened after (s)he becomes indicated for such screening. Let p denote the probability of transition from the indicated to the screened state. If a patient can undergo state transitions only at the time of a visit to the clinic, the time intervals between visits being i.i.d. Weibull(α, β), then the time to screening is the sum of a random number of Weibulls and does not have a recognizable distribution. However, given the number of visits (n) to the clinic, the distribution of the time to screening can be approximated by a Generalized Gamma distribution with parameters a , b and n where a and b depend on n and the Weibull parameters α and β . The m.l.e.'s of α , β and p are found (when right censoring of data is allowed) by taking advantage of the property of stochastic renewal at each visit epoch. These are used to find the m.l.e.'s of a and b for a given value of n . The values \hat{a} and \hat{b} (for each value of n) and \hat{p} are then used in a weighted sum of Generalized Gamma distributions to estimate the c.d.f. of the time to screening. Finally probability estimates computed directly from simulated data are compared with the m.l.e. obtained using the proposed model.

LET'S MAKE A DEAL: THE PLAYER'S DILEMMA. J. P. Morgan, N. R. Chaganty*, R. C. Dahiya*, and M. J. Doviak*, Dept. of Math. & Stat., Old Dominion Univ., Norfolk, Va. 23529. In a trio of recent columns entitled "Ask Marilyn" in *Parade Magazine* (September 9, 1990, December 2, 1990, and February 17, 1991) the following question was posed: "Suppose you're on a game show and given a choice of three doors. Behind one is a car; behind the other two are goats. You pick door No. 1, and the host, who knows what's behind them, opens No. 3, which has a goat. He then asks if you want to pick No. 2. Should you switch?" This problem has been long known in guises such as the prisoner's dilemma of Mosteller (1965), and this is not the first time it has been the focus of a lively debate. The current setting, however, opens questions not addressed in previously published solutions. These questions will be explored here, along with a look at some of the more popular false solutions and a brief treatment of the problem's history.

CONSTRUCTION OF OPTIMAL DESIGNS FOR THE LOGISTIC MODEL. William R. Myers, Dept. of Biostatistics, MCV Station, Box 32, Medical College of Virginia, Va. Commonwealth Univ., Richmond, Va. 23298-0032. Logistic regression is widely used to relate a quantal response to the levels of one or more explanatory variables. Since this model is nonlinear an optimal design will depend upon the model parameters. Several different criteria (eg. D,G,Q,E optimality) have been found useful in designing linear models. For nonlinear models D-optimality has been extensively investigated. The purpose of this paper is to explore the use of several of these criteria for designing experiments for the logistic model. Robustness relative to initial parameter estimates is considered for some of these designs. In addition, a two stage experiment that forms optimal designs for various criteria is also constructed.

COMPARING AND PREDICTING TIME-RELATED, PATIENT SPECIFIC OUTCOMES AFTER INTERVENTION FOR HEART DISEASE. David C. Naftel,*Dept. of Surg., University of Alabama at Birmingham, Birmingham, AL 35294. Currently there are several treatments (medical therapy, coronary artery bypass surgery and percutaneous, transluminal coronary angioplasty) available for the patient with ischemic heart disease. Assessing the treatment of choice is a multi-dimensional process. In fact, the preferred treatment for a particular patient is a function of 1) patient specific characteristics, 2) treatment specific characteristics, 3) which outcome (death, return of angina, subsequent operation, etc.) is examined and 4) patient preferences regarding the possibly time-changing superiority of a treatment. Quantitatively evaluating and comparing treatments is a statistical challenge that should consider 1) the quantity, quality and source of the available data, 2) the available and implemented statistical methods and 3) the potential to translate the analytic results into interpretable and useful graphical formats. Statistical methods do exist that quantify this decision making process and aid the physician and patient in making informed decisions including the degree of uncertainty. This paper focuses on the statistical methodology (specifically parametric survival analysis) that can be and has been used for comparing treatments through time-related predictions of the probability of outcome after intervention for ischemic heart disease.

A NOTE ON GENERALIZED SPATIAL MEDIAN. Dayanand N. Naik, Dept. of Mathematics and Statistics, Old Dominion University, Norfolk, Va. 23529. This note is concerned with the derivation of a generalized spatial median (GSM). The equations obtained to derive the GSM are also the equations used to obtain the maximum likelihood estimates of parameters in a certain multivariate distribution. Using these maximum likelihood estimates, inference about the moment correlation coefficient in a bivariate situation is done. Results are illustrated using a simulated data set.

A STATISTICAL APPROACH TO ENVIRONMENTAL IMPACT ASSESSMENT.

Sungsue Rheem, Dept. of Stat., Va. Polytechnic Inst. & State Univ. and Eric P. Smith, Dept. of Stat., Va. Polytechnic Inst. & State Univ., Blacksburg, Va. 24061. The before-after control-impact (BACI) method is a powerful approach for evaluating the effect of the discharge from, for example, a chemical or power plant on the aquatic environment. Detection of the effect of the discharge is achieved by testing whether the difference between abundance of a biological population at a control site (upstream) and that at an impact site (downstream) changes once the discharge begins. This requires taking samples, replicated in time, before the discharge begins and after it has begun, at both the control and impact sites. Frequently the data set has problems that hinder simple analysis of the effect such as irregular sampling, outliers, a large number of zero values and trend in the data. In this talk, two of the problems, the problem of zeros and that of trend are discussed. First, an approach to analyzing the zero and nonzero data is described. In data without joint zeros, the difference between the control-site abundance and the impact-site abundance may be dependent upon the magnitudes of abundances and may have the trend. An analysis of covariance will be described to distinguish the effect of discharge from the effects of the magnitudes of abundances and the trend.

A GENERALIZED MODEL APPROACH TO FREQUENCY DOMAIN SPECTRAL ESTIMATION. Keith Selander and Robert V. Foutz*, Dept. of Stat., Va. Tech., Blacksburg, Va. 24061. Peter McCullagh (1983) outlined the theory of quasi-likelihood estimation in generalized models. Chiu (1988) showed that an iterated, reweighted least squares procedure applied to the periodogram produces estimates of spectral density model parameters for Gaussian univariate time series which have the same asymptotic variance as those produced by maximizing the true likelihood. In this paper, McCullagh's theory is combined with a functional analysis approach and extended to parametric estimation over frequency bands of the spectral density matrix components of a non-Gaussian bivariate time series. An asymptotic optimality theorem is given, which shows optimality of an iterated, reweighted least squares procedure within a class of procedures. Parametric cospectral estimation over frequency bands allows transfer function analysis of two non-Gaussian time series which are not necessarily ARMA processes when some frequency bands may be contaminated, and non-ARMA multivariate model fits.

DETERMINING THERAPEUTIC SYNERGISM IN A NONPARAMETRIC REGRESSION SETTING. E. Kenneth Sullivan, Dept. of Biostatistics, Med. Col. of Va., Va. Commonwealth Univ., Richmond, Va. 23298-0032. In multiple drug clinical trials it is of interest to estimate the drug levels which provide maximum therapeutic benefit. In particular, we want to know if there exists a drug combination with benefit superior to that provided by using either drug alone (i.e., therapeutic synergism). Statistical development in this area, up to now, has focused on parametric estimation. This includes the work of Carter, et al., who developed methods for calculating confidence regions about the stationary point and about the response at the stationary point useful in defining the existence of a therapeutic synergism. This paper presents a parameter-free estimate of the response surface stationary point and extends the work of Carter by considering the response at the stationary point in a nonparametric regression setting. Re-sampling techniques are used to construct a confidence region about the response at the stationary point, and a statistical test of therapeutic synergism is proposed.

A NEW APPROACH TO DESIGN AUGMENTATION. Sindee S. Sutherland* and Jeffrey B. Birch, Dept. of Stat., Va. Tech., Blacksburg, Va. 24061. We consider the response surface problem of augmenting designs by adding points sequentially to a new region of interest. The methods of sequential design augmentation through the use of performance criteria such as D-optimality or I_{sv} -optimality (minimizing integrated prediction variance over spherical regions) are used under the assumption of correct model specification. However, under model misspecification, the sequential placement of points in the new region of interest using either of the above optimality criteria may not be the most desirable. We present a new methodology, based on a modified kernel regression procedure called HATLINK, that incorporates model misspecification into its sequential augmentation of points to the new region. Our method is then compared to others for various degrees of model misspecification.

PERFORMANCE OF EWMA CHARTS IN THE PRESENCE OF CORRELATION, M.R. Reynolds and L. VanBrackle, 202 Ardmore Street, Blacksburg, VA 24060.

In Statistical Process Control, it is usually assumed that observations taken from the process at different times are independent with a constant mean and with variation due only to measurement error. In many processes this assumption of independence is not satisfied. The lack of independence of observations taken at different times may have a significant effect on the properties of a process monitoring technique.

We consider a first order autoregressive process which is observed subject to measurement error. We use both integral equation and Markov chain approaches to evaluate the average run length (ARL) of an exponentially weighted moving average (EWMA) control scheme used to monitor the process. The effects of correlation and measurement error on the ARL's of the EWMA scheme are studied for a process which is in control and for a process which has undergone a shift away from the target value.

Symposium—Biotechnology at Work

BIODEGRADATION OF SELECTED PESTICIDES UNDER ANAEROBIC CONDITIONS. Duane F. Berry, Ji-Dong Gu*, Ronald H. Taraban*, Hubert L. Walker, Jr.*, and D. C. Martens*, Dep. of Crop and Soil Environmental Sciences, VPI&SU, Blacksburg, VA. 24061. Many intentionally applied herbicides eventually end up in non-targeted areas such as wetlands, sediments, and groundwater where anaerobic conditions often prevail. We evaluated the biodegradability of atrazine, cyanazine, and dicamba in wetland soils under nitrate reducing and methanogenic conditions. Wetland soil samples from two different wetland areas located near the Chesapeake Bay were used to set up air tight serum bottle microcosms, containing soil, mineral-salts medium, and herbicide. Samples were withdrawn periodically by syringe to determine concentrations of methane (headspace), nitrate, and herbicide. Dicamba was degraded in both soils within 60 days under methanogenic conditions and in only one of the soils under nitrate reducing conditions. Since sterile controls for 2 of the 4 situations tested failed, transfer cultures were initiated in an effort to substantiate the biodegradability of dicamba. Decreases in concentration of atrazine and cyanazine occurred over an 8-month incubation time period in both soils under either nitrate reducing or methanogenic conditions (autoclaved sterile controls showed concentration decreases). Our results provide strong evidence that dicamba is biodegraded in wetland soils under anaerobic conditions. Evidence indicating that atrazine and cyanazine were biodegraded was not as convincing.

PLANT STRESS RESISTANCE: APPLICATIONS OF BIOTECHNOLOGY. Carole L. Cramer, Dept. of Plant Pathol., Physiol., and Weed Sci., Va. Polytechnic Inst. and State Univ., Blacksburg, Va. 24061-0330. Plants have evolved complex mechanisms for surviving biotic and abiotic stresses. Technologies based on recombinant DNA and genetic transformation of plants provide new tools for understanding the molecular basis of stress resistance and new strategies for engineering enhanced resistance. We have cloned tomato genes encoding 3-hydroxy-3-methylglutaryl CoA reductase (HMGR), a major rate-limiting enzyme of isoprenoid synthesis. HMGR activity is highly induced during expression of disease resistance associated with the synthesis of isoprenoid phytoalexin antibiotics. Specific HMGR genes are differentially expressed during normal development and in response to wounding or pathogen challenge. We are currently developing procedures to generate transgenic tomato roots and plants to analyze stress-related HMGR gene regulation and promoter function and to address whether altered levels of HMGR affect disease resistance.

BIOLOGICAL NITROGEN FIXATION. Dennis R. Dean, Dept. of Anaerobic Microbiology, Virginia Polytechnic Institute and State University, Blacksburg, Va. 24061. Biological nitrogen fixation is catalyzed by nitrogenase, a complex metalloenzyme composed of two component proteins, called the Fe protein and the MoFe protein. Together, these two proteins catalyze the ATP-driven six-electron reduction of dinitrogen to ammonia with the concomitant evolution of dihydrogen. Effort from this laboratory is focused on elucidation of the molecular mechanism of biological nitrogen fixation. Towards this end we have isolated and characterized more than 35 genes whose products are known to be involved in the process. In addition, we have developed gene and site-directed mutagenesis strategies for elucidating the specific biochemical functions of the individual gene products. Finally, we have used site-directed mutagenesis techniques and biochemical and biophysical characterizations of altered nitrogenase component proteins to identify residues required for its catalytic activity.

SECONDARY METABOLITES. Walter Niehaus, Department of Biochemistry, V.P.I., Blacksburg, VA 24061. Secondary metabolites are compounds which have complex chemical structures, are biosynthesized by a limited group of organisms, and which are not required for the growth of the producing organism. Indeed, in most cases we do not know the physiological role played by the secondary metabolite in the life of the producing organism. Nevertheless, secondary metabolites are of great importance to mankind, as this class of compounds includes most of our antibiotic drugs, several anticancer drugs and cholesterol-lowering drugs, as well as a number of highly toxic or carcinogenic agents. The role of biotechnology is to introduce modifications into the producing organisms in order to increase yields of desirable secondary metabolites, or to decrease or eliminate production of undesirable secondary metabolites. In this talk I will consider two secondary metabolite groups: the β -lactam antibiotics such as penicillins and cephalosporins; and the polyketide mycotoxins such as aflatoxin and sterigmatocystin. I will briefly describe biotechnological approaches that have been successfully applied by scientists at Lilly to increase production of the antibiotics. I will discuss the current state of biotechnological approaches to the mycotoxin problem, including some work that has been done in my laboratory.

ANIMALS AS BIOREACTORS. Tracy D. Wilkins, Dept. of Anaerobic Microbiology, Va. Tech Blacksburg, VA. Recombinant DNA techniques are now used to produce simple human proteins in bacteria and yeast. Many other human proteins are so complex that only mammalian cells can produce them correctly. A multidisciplinary team at Va Tech is now attempting to produce such proteins in the milk of farm animals. Human genes controlled by mouse regulatory DNA have now been inserted into the chromosomes of pigs. These pigs are now being milked to determine whether the human proteins have been successfully expressed in the milk. If these experiments are successful many lives will be saved by the use of these proteins - which will be purified from the milk and injected into patients who require them.

GENOMIC ORGANIZATION AND EXPRESSION OF THE OVINE INSULIN-LIKE GROWTH FACTORS. Eric A. Wong and Susan M. Ohlsen*, Dept. of Animal Science, Va. Polytechnic Inst., Blacksburg, Va. 24061. The insulin-like growth factors (IGFs) are small peptides which are structurally related to insulin and possess growth-promoting activity. IGF-I is a 70 amino acid peptide which is thought to be the major mediator of the biological effects of growth hormone and therefore is a key regulator of postnatal mammalian growth. IGF-II is 67 amino acids in length and is postulated to act as a fetal growth regulator. To study the molecular regulation of the IGFs in ruminants, we have cloned complementary DNAs (cDNAs) encoding ovine IGF-I and -II. The ovine IGFs show greater than 92% amino acid identity with other mammalian IGFs. The expression of messenger RNAs (mRNAs) encoding ovine IGF-I and -II is complex. mRNAs containing different first exon sequences have been identified and are presumably generated by alternative RNA processing. The gene for ovine IGF-I has been cloned and partially sequenced. Ovine IGF-I contains five exons and spans greater than 50 kilobases of DNA. Current research efforts are focused on a molecular analysis of the regulatory regions which control the expression of these important growth factor genes.

USE OF ANTHER DERIVED HAPLOIDS IN POTATO BREEDING. Richard E. Veilleux, Dept. of Horticulture, Va. Polytechnic Inst. and State Univ., Blacksburg, Va. 24061. One of the major contributions of plant breeding in the twentieth century has been the development of hybrid cultivars of major crops, such as maize. Hybrids are only possible through cross pollination of selected homozygous inbred lines, usually obtained by self-pollination for several generations. For many crops, including potato, inbred lines are unavailable due to severe inbreeding depression or barriers to self-pollination. Through culture of anthers, the male reproductive organ of plants, immature pollen grains of selected genotypes can be induced to become embryogenic and develop into plants with the gametophytic or haploid chromosome number. By doubling the chromosome number of such haploids, the equivalent of inbred lines can be obtained within only a single "generation." We report the development of such androgenetically derived inbred lines of *Solanum phureja*, a cultivated South American potato species, and their breeding behavior in test crosses. The progenies of some anther-derived inbred lines were found to be superior for yield attributing characteristics than the original heterozygous plant from which they were derived, indicating considerable potential for this technique in potato improvement.



**The Virginia Academy of Science
Ivey F. Lewis
Distinguished Service Award**



ROBERT DEAN DECKER

Dedicated leader of the Virginia Junior Academy of Science, loyal servant of the Virginia Academy of Science and the University of Richmond, Robert Dean Decker is an excellent choice to be honored with the Ivey F. Lewis Distinguished Service Award of the Academy. His highly responsible devotion to the science education of the young is an inspiration to all.

Dr. Decker, a native of Indiana, is Associate Professor of Biology at the University of Richmond. He attended secondary school in Indiana, received his BS and MS degrees from Purdue University and Ph. D. degree from North Carolina State University in 1966 in Botany. He has been teaching plant physiology and introductory biology. He recently developed highly innovative introductory biology courses for non-majors and his most recent research efforts have been in the development of curricula and teaching strategies for these courses. In this regard he is quite active in the state and nationally.

Dean has been Director of the Virginia Junior Academy of Science since 1981. Under his dynamic leadership the VJAS has not only tripled in size but also has experienced great increase in activity and quality. The VJAS now is one of the top Junior academies in the country. His tireless efforts in fund raising have brought significant support to the VJAS. He has been particularly effective in the establishment of college scholarships which are awarded to winners of the research competitions at the annual meeting. Dr. Decker is an expert in the establishment and development of state junior academies and is regularly called upon to present workshops and technical advice.

Dean has been involved with the leadership of the American Junior Academy of Science since 1982. His activities have included serving as a photographer and as assistant to the Director, Dallas Cocke. When Mrs. Cocke became ill, Dean became Acting Director of the AJAS until his appointment as Director. In this capacity he has been most successful in setting up the Annual Meetings of the AJAS and serving as an expert advisor to directors of state Junior academies. These efforts have been recognized and he was honored with the Distinguished Service Award of the National Association of Academies of Science in 1988. Dean also finds time to be involved in other areas of the Virginia Academy of Science. In addition to being a member of the Executive Council and Council of the VAS he has been active and effective as a member of several other committees over the years. For his many contributions the Academy wisely chose to honor him as a Fellow of the Academy in 1983.

It therefore seems most appropriate in this year of the 50th Anniversary of the Virginia Junior Academy of Science to present the Ivey F. Lewis Award to Robert Dean Decker, an outstanding member of the Academy.

ACADEMY FELLOW



MARTHA ANN KOTILA ROANE

The Virginia Academy of Science has honored Martha Ann Kotila Roane, adjunct professor at Virginia polytechnic Institute and State University as a Fellow of the Academy, recognizing her service to the Academy and her profession.

Roane has been an active member of the academy for two decades and has served as secretary and treasurer, chaired the Botany section, Flora Committee, Public Relations subcommittee and Long Range Planning Committee, edited *Jeffersonia* and held other offices.

She is also an active member of the American Phytopathological Society, Mycological Society of America, Rhododendron Society of America, Sigma Xi, Omicron Delta Kappa, and is listed in *American Men and Women of Science* for her work on taxonomy of higher plants, especially rhododendron and fungi (*Endthia*).

Roane earned a B.S. from Michigan State University in 1944, an M.S. from the University of Minnesota in 1946 and her Ph.D. from VPI & SU in 1971.

Before becoming a doctoral student, she taught math at VPI for 7 years and at Radford for 5 years. She also was assistant Director of the Office of Institutional Research at Radford.

After earning her Ph.D., she became coordinator of the General Biology Laboratories at VPI & SU, was curator of fungi and an adjunct professor, first in botany and later in plant pathology and physiology.

She has also been a faculty advisor, chaired the advisory board of the Virginia Tech Chapter of the Alpha Phi Omega service fraternity, has served as faculty advisor of the Student Service Council and was a member of the advisory board of the Virginia Museum of Natural History.

EXECUTIVE COMMITTEE MINUTES

March 2, 1991 Virginia Tech

Present: Richard Brandt (President), Gerald Taylor (President-Elect), Elsa Falls (Secretary), Carolyn M. Conway (Treasurer), Michael L. Bass (Immed. Past-President), Blanton Bruner (Executive Secretary-Treasurer), Vera B. Remsburg (Rep. to Science Museum of Va. Board), Arthur Burke (Chair, Finance and Endowment Committee), R. Dean Decker (VJAS), Golde Holtzman (Local Arrangements Chair), Roy S. Jones (Visitor, representing Donaldson Brown Center at Va. Tech)

The meeting was called to order at 10:00 a.m. by President Richard Brandt.

Local Arrangements Committee Report by Golde Holtzman, Chair.

A budget estimate for the Annual Meeting in May 1991 was distributed (attached), which was prepared using figures from last year's meeting at GMU as a guide.

Dr. Holtzman indicated that at present twelve schools will have exhibits, but there are no commercial exhibits, with the deadline having been last Friday. He distributed information that went to potential exhibitors (attached). Michael Bass volunteered to contact two commercial exhibitors who he was sure would want to exhibit.

Dean Decker predicted that attendance at VJAS might be affected by the location of the Meeting in southwest Virginia and by financial constraints presently being experienced by the schools. Vera Remsburg suggested that attendance by schools in southwest counties be encouraged by sending meeting notices directly to school principals.

After discussion, it was the consensus of the group to leave VAS student member and non-member registration fees the same as they had been at GMU.

The need to include liability insurance and medical coverage for VJAS participants was discussed. The consensus of the group was recognition that Virginia Tech had to charge for such protection and that two dollars should be added to VJAS fees to cover these expenses, raising the registration and room charge for a double to \$79 and a single to \$92. This insures that students can be treated at the Virginia Tech Infirmary, or at Montgomery County Hospital, and the costs will be covered up to \$2500 per student per incident. Mention will be made on the VJAS registration form that fees include liability insurance and medical coverage.

Gerald Taylor raised the question as to whether the Academy needs to have participants at the Annual Meeting sign a general waiver of liability. Arthur Burke did not consider it necessary.

Golde Holtzman distributed an outline showing the Local Arrangements Committee's structure (attached) and a draft of the VAS and VJAS Program (attached). Minor changes were suggested, and the following issues were discussed:

1) For the first time, the President will be hosting a luncheon for new section officers as well as each outgoing section chair. The purpose of the luncheon,

which will occur on Thursday at noon during the Annual Meeting, will be to improve communication. Arthur Burke indicated that funding for the luncheon can come from the President's contingency fund or from the fund for committee communication, rather than from Annual Meeting receipts.

2) Gerald Taylor announced his intention to call a VAS Executive Committee officer's meeting on Friday morning of the Annual Meeting.

3) It was agreed to leave the VJAS registration fee (no meals or lodging) at \$15. Vera Remsburg suggested that the amount of the fee needed to be reconsidered at a later time, since a fee of that size might discourage high school students from visiting the Meeting.

4) Carolyn Conway suggested rewording of the call-for-papers form and the abstract form to reflect the current requirement that student presenters must be members of VAS.

5) It was agreed that the cost for attending the VAS Banquet would be \$18.50. President Brandt and Dr. Holtzman will develop a list of invited guests to be given free tickets.

Golde Holtzman distributed an outline showing lodging costs (attached). He indicated that information for campus room reservations and a list of area motels will be included in registration packets. Virginia Tech is also planning to offer campus tours for VJAS registrants (description of proposed tours attached).

Report of the Committee on Nominations and Elections by the President for William Banks.

The following nominations for VAS 1991-1992 officers will be presented at the afternoon Council meeting: for president-elect, Elsa Q. Falls and Golde Holtzman; for secretary, Carolyn M. Conway and James O'Brien; for treasurer, Hugo Seibel and Thomas Sitz.

Approval of Executive Committee Minutes of November 4, 1990.

The minutes of the Executive Committee meeting of November 4, 1990, were approved as distributed, as moved by Carolyn Conway and seconded by Michael Bass.

Virginia Junior Academy of Science Report by Dean Decker.

1. Dr. Decker informed the group that progress was being made on plans for the reorganization of VJAS and the initiation of a fund-raising campaign. He distributed a draft of the Report of Planning and Feasibility for the Virginia Academy of Science prepared by Mary Ellen Stumpf, fundraising and public relations counsel (attached).

2. Dr. Decker announced that he has submitted to the President a letter of resignation from his position as Director of VJAS, effective at the close of the Annual Meeting in May 1992.

Because of time constraints, other reports were postponed until the afternoon Council meeting; it was suggested that Executive Committee meetings ought to

begin earlier in the future. The meeting was adjourned by President Brandt at 12:20 p.m.

Respectfully submitted by:
Elsa Q. Falls, Secretary
Virginia Academy of Science

VIRGINIA ACADEMY OF SCIENCE COUNCIL MINUTES

March 2, 1991 Virginia Tech

Present: Richard Brandt (President), Gerald Taylor, Jr. (President-Elect), Elsa Falls (Secretary), Carolyn Conway (Treasurer), Blanton Bruner (Executive Secretary-Treasurer), Michael L. Bass (Immediate Past President), Arthur Burke (Chair, Finance and Endowment Committee), Vera B. Remsburg (Rep. to Science Museum of Va. Board), Carvel Blair (Councilor, Environ. Sci. and Chair of ad-hoc Comm. on Environ.), Tom Sitz (Chair, Research Committee), Harold M. Bell (Director, Visiting Scientists Program), R. Dean Decker (Director, VJAS), J. J. Murray (Chair, Awards Committee), D. Rae Carpenter, Jr. (Chair, Trust Committee), Lisa Alty (Medical Science Section Councilor)

The meeting was called to order at 1:35 p.m. by President Richard Brandt.

Approval of Council Minutes of November 4, 1990.

The minutes of November 4, 1990, were approved with minor corrections, as moved by Rae Carpenter and seconded by Dean Decker.

President's Report by Richard Brandt.

1. The President read correspondence (attached) he had received from Dr. Elske P. Smith, Dean of Humanities and Science at VCU, requesting that VAS participate as a co-sponsor in a statewide symposium in the fall with undergraduate students and others presenting their research, as part of the Annual Virginia Alliance for Minority Participation in Science and Engineering. He also read his response (attached), agreeing to co-sponsorship. He explained the necessity for response on short notice, without prior Council approval. It was moved by J. J. Murray and seconded by Gerald Taylor that Council approve the action of the President to co-sponsor the symposium. The motion passed unanimously.

2. Dr. Brandt indicated that there is at present no firm commitment from any institution to host the 1992 Annual Meeting. He has, however, sent a letter (attached) to Dr. Richard Morrill, President of the University of Richmond, urging that his university agree to host that meeting. He has received no report from Stewart Ware on the possibility of William and Mary's hosting a future meeting. He will try to encourage ODU to commit for 1993, and there are other potential sites for '94, '95, and '96. Gerald Taylor stated he hoped he could make a more definite report at the May Council meeting.

3. He promised to have a complete directory ready by the Annual Meeting, to be distributed to all registrants.

4. He announced that the Commonwealth's Lifetime Achievement Award in Science has been given to John Cairns, Jr. of Virginia Tech's Biology Department, who is also a VAS member. He thought it appropriate that the winner be announced at the Annual Meeting, as well as previous award winners who are also VAS members.

Local Arrangements Committee Report by Gerald Taylor for Golde Holtzman.

Because Dr. Holtzman had become ill, Dr. Taylor reported for him, commenting on the superb job that was being done by Dr. Holtzman as Chair of the Committee.

He asked that VAS members be encouraged to come as early as possible to the Annual Meeting in order to attend the Wednesday picnic and VJAS/VAS joint general session to celebrate the 50th Anniversary of VJAS.

He highlighted a number of Annual Meeting events, including: the VAS reception Wednesday evening at the Virginia Museum of Natural History, a President's luncheon for section officers on Thursday, the Negus Lecture at 5:30 on Thursday by Paul Knappenberger, a Thursday symposium ("Biotechnology at Work"), and a Friday symposium sponsored by the Biology Section ("Land Use Patterns and Impacts on the Biota of Virginia").

President-Elect's Report by Gerald Taylor.

Dr. Taylor's report (attached) included the following information:

1. In January he met with President Brandt, Dean Decker, and Golde Holtzman and some of his associates at Virginia Tech to work out Annual Meeting details.

2. He mailed to all section officers in January **A Schedule of Responsibilities for 1990-91**, a **Sample Plan for Section Meetings** at the Annual Meeting, a revised **Job Description for Section Officers**, and **Instructions for Section Editors**. Responses from officers have been very positive.

3. There will probably be in excess of 200 papers presented at VAS.

4. Organization of the Computer Science Section is progressing, with considerable interest being shown.

5. He will be sending a letter to each VAS member asking him/her to recruit two new members; included with the letter will be two membership invitations (attached).

In response to a question from Rae Carpenter, Dr. Taylor stated that the proposed Archaeology Section has papers scheduled to be presented. Also, the Agriculture Section will have a business meeting, but no papers will be presented.

Rae Carpenter asked when a VAS membership list would be published again. Dean Decker suggested the list might accompany an issue of The Journal and should include a directory of officers. Tom Sitz suggested that committee members as well as chairs be included in such a listing. Gerald Taylor hoped that a membership list could be combined with a directory of officers and committees and mailed by early fall.

Secretary's Report by Elsa Falls.

The secretary requested that anyone presenting reports or making motions submit a copy to her in writing.

Treasurer's Report by Carolyn Conway. No report.

Past President Michael Bass. No report.

Executive Secretary-Treasurer's Report by Blanton Bruner. No report.

Virginia Junior Academy of Science Report by Dean Decker.

Dr. Decker announced that he has submitted to the President a letter of resignation from his position as Director of VJAS, effective at the close of the Annual Meeting in May 1992.

He reported that:

1. The number of papers to be presented at VJAS in May will probably be down, due to school budgetary constraints.

2. The Regionalization Committee has had one meeting since November, and implementation plans are progressing.

3. A draft of the Report of Planning and Feasibility for the Virginia Academy of Science has been prepared by Consultant Mary Ellen Stumpf and contains recommendations relative to VJAS office location, job descriptions of executive director and support staff, establishment of a "lay" board, and execution of a fund-raising campaign.

Dr. Decker indicated that the Fund-Raising Committee would be meeting with the consultant to discuss her recommendations. Gerald Taylor suggested that a professional fund-raiser be hired. Rae Carpenter suggested that a data base of winners of VJAS awards and their parents is needed because they are the ones who would support the Academy in future years. Dr. Decker asked if it would be appropriate to announce the campaign at the May meeting; Elsa Falls responded that it was premature, in that leadership gifts must be secured before announcing the campaign to the public. Dr. Brandt requested that the Fund-Raising Committee meet and make recommendations at the May meeting on how to proceed.

It was moved by Gerald Taylor and seconded by Arthur Burke that the consultant and Fund-Raising Committee receive appreciation of Council for the preliminary draft report and be informed that Council looks forward to a final report and recommendations in May. The motion passed unanimously.

Virginia Journal of Science Report by Richard Brandt for Jim Martin, Editor.

There are no problems at present; there is a backlog of about 25 papers to be published.

Report of Director of Visiting Scientists Program by Harold Bell.

Work on the 1991-92 program has begun. Next week letters will go out to college presidents asking for their support once again.

Carolyn Conway suggested that communication with college presidents may not be the best way to insure that information reaches professors. Dr. Bell suggested that he could send a postcard with his communication asking presidents to designate persons who would be responsible for the program, with whom he could then communicate. Dr. Bass commented that the program was

very successful in attracting potential visiting scientists, and Dr. Bell added that a bigger problem is getting schools to use the visiting scientists. Gerald Taylor suggested sending a letter to teachers of VJAS presenters telling them about the program.

Michael Bass requested that the President send a letter to Harold Bell thanking him for his excellent work in organizing the Visiting Scientists Program, with a copy of the letter going to the President of Virginia Tech.

AAAS Report by Dean Decker for Ertle Thompson, AAAS Representative.

Fifty-six high school students, four from Virginia, attended the American Junior Academy of Science. Dr. Decker attended the National Association of Academies of Science meeting and found that state academies were not well-represented and many were not very active.

Archives Report by Richard Brandt for Martha Roane.

Martha Roane requested that members send archival material to Glen McMullen at the Newman Library at Virginia Tech and that they send letters to her so she will be aware of what has been sent.

Awards Committee Report by Jim Murray.

Dr. Murray indicated in his report (attached) that the Awards Committee has nominated Martha K. Roane for a Fellowship in the Academy and intends to award an Ivey F. Lewis Distinguished Service Award, the recipient to be announced at the Annual Meeting.

Constitution and By-Laws Committee.

There was no report, but President Brandt indicated the Committee will have recommendations to be acted on at the Academy Conference in May.

Committee on Science Education. No report.

Report of Finance and Endowment Committee by Arthur Burke.

Dr. Burke distributed the approved budget for 1991 with actual figures for 1990 included, these having been unavailable at the November Council meeting (attached). He pointed out that there is still no final accounting from the 1990 Annual Meeting held at GMU, but income from that meeting is estimated to be about \$17,000. Because membership for 1991 is 1059 members, compared with 1108 members for 1990, income from dues has been adjusted down in the revised budget for 1991. It is estimated that we will run a deficit of \$8000-\$10,000 in 1991, which will necessitate a drawdown from the General Fund, which means we are having to use our general reserves. Dr. Burke suggested that Council needed to consider how to get the Academy back into a positive cashflow situation.

The necessity of receiving the income from the GMU Meeting as soon as possible was discussed. It was moved by Rae Carpenter and seconded by Dean Decker that the President write to the GMU Local Arrangements Chairman, with a copy to his Dean or other higher official, expressing the concern of the Academy Council that the VAS has not yet received final accounting and

payment for the Annual Meeting held in May 1990 at GMU. The motion was passed unanimously.

Fund Raising Committee. There was no report, other than that given by Dean Decker during his earlier report for VJAS.

Long Range Planning. No report other than that given by Dr. Brandt in his President's report.

Report of Committee on Nominations and Elections by Michael Bass for William Banks.

The report (attached) indicated that the following slate for 1991-92 officers has been selected: for president-elect, Elsa Q. Falls and Golde I. Holtzman; for secretary, Carolyn M. Conway and James P. O'Brien; and for treasurer, Hugo R. Seibel and Thomas O. Sitz.

Membership Committee Report by the President for Hugo Seibel.

He has sent letters to all pre-med advisors asking them to join VAS. A letter has been sent to each Section Secretary with membership information enclosed.

The problem of declining membership was discussed. Carvel Blair suggested sending membership information to various state agencies. Carolyn Conway commented that she feels that VAS is not viewed as very important by some deans and departmental members. Michael Bass pointed out that travel funds are more limited than ever, and persons who attend or present papers at VAS are not always rewarded by their superiors. Lisa Alty predicted that Virginia Scientists will increase the visibility of VAS and lead to more members.

Research Committee Report by Tom Sitz.

He reported that the names of 1990 Horsley Cancer Research grantees were published in the March 1991 issue of Virginia Scientists. He has had calls from people about small project grants from institutions from which there have never been inquiries before; these inquiries are probably due to publicity in Virginia Scientists.

Science Advisory Committee.

President Brandt announced that the new chairman of this committee is William Dewey, who will attempt to make the committee active rather than reactive.

Trust Committee Report by Rae Carpenter.

Dr. Carpenter submitted a report (attached) listing current holdings in all Academy funds showing cost basis, recent price, worth as of December 31, 1990, and proceeds from a security called in 1990. His written report also listed income gifts and disbursements for each of the funds held in the portfolio. He indicated it was not necessary in 1990 to transfer funds from the General Fund to supplement operating funds. The total value of all funds as of February 28, 1991, was \$165,880, compared to \$153,379 on December 31, 1990 and \$157,696 on July

20, 1990. He stated that the Committee is pleased with the performance of the funds in which VAS has invested; they consist of approximately 50% bonds and 50% growth stocks, resulting in protection as well as some opportunity for growth.

Virginia Flora Committee. No report.

Report of News and Publicity Committee by Richard Brandt for James O'Brien.

Dr. Brandt distributed a written report (attached) prepared by Chairman O'Brien. Media packages are being prepared for the Annual Meeting. It is hoped that exhibitor information will be available for inclusion in the Annual Meeting Program. Susan Trulove (Virginia Teach PR Annual Meeting Local Arrangements Committee Representative) is coordinating with Dean Decker publicity regarding VJAS winners in hometown newspapers. New certificates of appreciation are available for the May meeting from Dr. O'Brien. Data on Virginia Scientists concerning copies produced and costs were provided; the deadline for the next issue is July 1, 1991; Dr. O'Brien requested that persons knowing someone who should receive a complimentary copy should contact him. He indicated the need for a membership directory and recommended that Council appoint an editor in sufficient time to gather the necessary information at the May meeting.

Report by Representative to the Science Museum of Virginia, Vera Remsburg.

The Science Museum Board will meet in Reston, Virginia, in April. She thanked VAS members who attending the January 28th reception held at the Museum for the General Assembly. She will seek the assistance of VAS Fellows in carrying out a Science Museum project when they meet in May.

Medical Science Section Report by Lisa Alty.

The Medical Sciences Section will discuss at the Annual Meeting the possibility of the Microbiology Section, which is not very active, combining with Medical Science, which is very active. Dr. Brandt suggested that Dr. Alty contact Jim O'Brien about an article in Virginia Scientists on the Medical Science Section.

Psychology Section Report by Richard Brandt for James O'Brien.

A written report (attached) was submitted which included the announcement that the Board of Directors of the Virginia Psychological Foundation has approved an annual donation of \$280 to support awards for outstanding VJAS papers in psychology.

Report of the Ad Hoc Committee on the Environment by Carvel Blair.

Dr. Blair's report (attached) included information on the first Committee project undertaken, which consisted of reviewing the report of a field test of a rabies glycoprotein recombinant vaccine on wild raccoons on Parramore Island in the Nature Conservancy's Eastern Shore Reserve; the Committee concluded

that the study is being carefully and thoroughly done, with appropriate precautions. The Committee intends to request copies of the final reports and to recommend that the reports be sent to the Conservancy, the Virginia Department of Game and Inland Fisheries, and the Virginia Department of Health for review. Dr. Brandt indicated it was appropriate for the Science Advisory Committee to become involved in submitting such recommendations.

Old Business.

Dean Decker noted that he must receive from the various Sections their nominees for awards of honorary membership in AAAS to two college students who present papers at the Annual Meeting; no awards were made last year due to a breakdown in communication. Dr. Taylor indicated that he has notified Section Officers that they must get their nominees to him as President-Elect. He will choose the winners and notify Dr. Decker. This procedure will have to be made clear at the luncheon for Section Officers on Thursday during the Annual Meeting. A suggested procedure for future years will be brought to Council by Dr. Brandt and Dr. Taylor after it is determined how well the process goes this year.

New Business.

It was moved by Gerald Taylor and seconded by Carvel Blair that Council approve a \$300 Science Museum of Virginia Representative Travel Fund for 1991-1992, unless funding comes forward from the State; a summary report on use of these funds is to be presented to the Executive Committee by May 1992 for accounting purposes. James Murray objected to the Academy's funding something that the State should provide. The motion passed.

It was moved by Gerald Taylor and seconded by Lisa Alty that Council direct the VAS Executive Secretary-Treasurer to provide \$200 for President Brandt and his wife to attend the Awards Banquet for the Virginia Scientist and Industrialist of the Year at the Science Museum of Virginia on March 25 as official representatives of VAS. The motion passed unanimously.

It was moved by Gerald Taylor and seconded by Carolyn Conway that Council authorize Dean Decker, Director of VJAS, to use \$200 to cover the expense incurred in order for he and his wife to attend the Awards Banquet for the Virginia Scientist and Industrialist of the Year at the Science Museum of Virginia on March 25 as official representatives of VAS. The motion passed unanimously.

Dr. Brandt announced that the State Public Education Committee of the American Cancer Society is donating \$500 for this year, to be used to award prizes for outstanding VJAs papers related to cancer research, rather than the lesser amount announced at the Council meeting in November. Further, they will provide plaques for the winners.

President Brandt adjourned the meeting at 4:47 p.m.

Respectfully submitted by :
Elsa Q. Falls, Secretary
Virginia Academy of Science

SUMMARY OF MOTIONS COUNCIL MEETING, MARCH 2, 1991

1. That Council approve the action of the President to co-sponsor the statewide symposium in the fall with undergraduate students and others presenting their research, as part of the Annual Virginia Alliance for Minority Participation in Science and Engineering. Moved by J. J. Murray and seconded by Gerald Taylor. **Motion passed unanimously.**
2. That the consultant and Fund-Raising Committee receive appreciation of Council for the preliminary draft report and be informed that Council looks forward to a final report and recommendations in May. Moved by Gerald Taylor and seconded by Arthur Burke. **Motion passed unanimously.**
3. That the President write to the GMU Local Arrangements Chairman, with a copy to his Dean or other higher official, expressing the concern of the Academy Council that the VAS has not yet received final accounting and payment for the Annual Meeting held in May 1990 at GMU. Moved by Rae Carpenter and seconded by Dean Decker. **Motion passed unanimously.**
4. That Council approve a \$300 Science Museum of Virginia Representative Travel Fund for 1991-1992, unless funding comes forward from the State; a summary report on use of these funds is to be presented to the Executive Committee by May 1992 for accounting purposes. Moved by Gerald Taylor and seconded by Carvel Blair. **Motion passed.**
5. That Council direct the VAS Executive Secretary-Treasurer to provide \$200 for President Brandt and his wife to attend the Awards Banquet for the Virginia Scientist and Industrialist of the Year at the Science Museum of Virginia on March 25 as official representatives of VAS. Moved by Gerald Taylor and seconded by Lisa Alty. **Motion passed unanimously.**
6. That Council authorize Dean Decker, Director of VJAS, to use \$200 to cover the expense incurred in order for he and his wife to attend the Awards Banquet for the Virginia Scientist and Industrialist of the Year at the Science Museum of Virginia on March 25 as official representatives of VAS. Moved by Gerald Taylor and seconded by Carolyn Conway. **Motion passed unanimously.**

Virginia Academy of Science
Small Project Grants
Funded (May 1991)

Milton J. Allen (\$900), Virginia Commonwealth University, Dept. of Chemistry, 1001 W. Main Street, Box 2006, Richmond, VA 23284-2006, An approach to the determination of surface charge on biological membranes.

Karen D. Holl and John Cairns, Jr. (\$840), Dept. of Biology, Virginia Polytechnic University and State University, Blacksburg, VA 24061-0406, Butterfly population dynamics on coal surface mined sites in Southwestern Virginia.

William C. Reay and George M. Simmons, Jr.(\$950), Dept. of Biology, Virginia Polytechnic University and State University, Blacksburg, VA 24061-0406, Estaurine sediment denitrification under the influence of ground water nitrate loading.

Darcy L. Russell (\$1000), Dept. of Biology, Washington & Lee Univ. Parmly Hall, Lexington, VA 24450, Sindbis virus mutants: Generation and characterization.

Alan H. Savitzky (\$810), Dept. of Biological Sciences, Old Dominion University, Norfolk, VA 23529-0266, The vascular morphology of infra-red receptors in snakes.

Joseph Topich (\$1000), Virginia Commonwealth University, Dept. of Chemistry, Box 2006, Richmond, VA 23284-2006, Versatile ligands for bioinorganic model complexes

AWARDS PRESENTED DURING THE VIRGINIA JUNIOR ACADEMY OF SCIENCE MEETING

AGRICULTURAL AND ANIMAL SCIENCE

Honorable Mention:	Martha C. Alter	H. B. Woodlawn
Honorable Mention:	Gretchen A. Dains	Thomas Jefferson High School for Science and Technology
Honorable Mention:	Evangelos B. Ringas	Denbigh High School
Third Place:	Brian M. Green	Williamsburg Middle School
Second Place:	Michelle Y. Yi	Swanson Middle School
First Place:	Mitzi G. McDougale	Lee-Davis High School

ANIMAL BEHAVIOR (ETHOLOGY)

Honorable Mention:	Elena M. Durso	Wakefield High School
Honorable Mention:	Stephanie M. Hamilton	Ferguson High School
Honorable Mention:	James S. Kellam	Midlothian High School
Third Place:	Cynthia L. Weaver	Patrick Henry High School
Second Place:	Jamie L. Robinson	Kempsville High School
First Place:	Kimberly M. Costello	Yorktown High School

BOTANY 'A'

Honorable Mention:	Melissa L. Buchanan	William Fleming High School
Honorable Mention:	Christine Drombetta	Cave Spring High School
Honorable Mention:	Kimberly L. Goodman	Williamsburg Middle School
Third Place:	Michael J. Delp	Swanson Middle School
Second Place:	Susan R. Busic	Patrick Henry High School
First Place:	Sneha S. Amin	Patrick Henry High School

BOTANY 'B'

Honorable Mention:	Jennifer S. Levin	Roanoke Valley Governor's School for Science and Technology
Honorable Mention:	Ashley B. Marcus	Gildersleeve Middle School
Honorable Mention:	Meg A. O'Connor	Kempsville High School
Third Place:	Hassan I. Huq	Monacan High School
Second Place:	Ajay Jain	Monacan High School
First Place:	Laura M. Pottmyer	H. B. Woodlawn

BOTANY 'C'

Honorable Mention:	Aditya N. Seth	Thomas Jefferson High School for Science and Technology
Honorable Mention:	Deaette M. Smith	Armstrong High School
Honorable Mention:	Susan R. Starkey	Central Virginia Governor's School
Third Place:	John S. Will	Thomas Jefferson Middle School

Second Place:	Daniel A. Tillman	Yorktown High School
First Place:	Sheri L. Thompson	Menchville High School

CHEMISTRY 'A'

Honorable Mention:	Marc E. Bejarano	Thomas Jefferson High School for Science and Technology
Honorable Mention:	Anne C. Christenson	Yorktown High School
Honorable Mention:	Suzanne M. Lassiter	Gildersleeve Middle School
Third Place:	Abdul G. Khan	Thomas Jefferson High School for Science and Technology
Second Place:	Eli Chen	Thomas Jefferson High School for Science and Technology
First Place:	Mark J. Gelman	Thomas Jefferson High School for Science and Technology

CHEMISTRY 'B'

Honorable Mention:	Andrew K. McAllister	Williamsburg Middle School
Honorable Mention:	Anna M. Nazaretz	H. B. Woodlawn
Honorable Mention:	Michele H. Son	Thomas Jefferson High School for Science and Technology
Third Place:	Alison E. Meekhof	Thomas Jefferson High School for Science and Technology
Second Place:	Victor F. Stone, Jr.	Thomas Jefferson High School for Science and Technology
First Place:	Michael A. Tolin	Thomas Jefferson High School for Science and Technology

COMPUTER SCIENCE

Honorable Mention:	Jonathan T. Blocksom	Thomas Jefferson High School for Science and Technology
Honorable Mention:	Andrea I. Kellum	Patrick Henry High School
Honorable Mention:	Kevin R. Walker	Monacan High School
Third Place:	Salvatore K. Bavuso	New Horizons Governor's School for Science and Technology
Second Place:	Adam L. Ginsburg	Yorktown High School
First Place:	Kristie L. Seymore	New Horizons Governor's School for Science and Technology

CONSUMER SCIENCE 'A'

Honorable Mention:	Lisa M. Deyerle	Cave Spring High School
Honorable Mention:	Jennifer J. Hall	Patrick Henry High School
Honorable Mention:	Amy F. Hopkins	Liberty Middle School
Third Place:	Jeffrey J. Hanten	Lee-Davis High School
Second Place:	Carmen Patrick	Homer L. Hines Middle School

First Place:	William T. Hockett	Gildersleeve Middle School
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CONSUMER SCIENCE 'B'

Honorable Mention:	Meha M. Shah	Gildersleeve Middle School
Honorable Mention:	Matthew T. Walsh	Swanson Middle School
Honorable Mention:	Chris L. Waugaman	Meadowbrook High School
Third Place:	Ronald L. Tidd	Lee-Davis High School
Second Place:	Warren S. Overholt	Williamsburg Middle School
First Place:	Steven M. Tinkey	Liberty Middle School

EARTH SCIENCE

Honorable Mention:	Elizabeth A. Jenkins	Yorktown High School
Third Place:	Kristin B. Miller	Meadowbrook High School
Second Place:	Ernst H. Kastning, III	Radford High School
First Place:	Emily C. Paulson	Gildersleeve Middle School

ENGINEERING 'A'

Honorable Mention:	David J. Baker	Menchville High School
Honorable Mention:	Ellison M. Cale	Ferguson High School
Honorable Mention:	Brandy K. Fields	Dozier Middle School
Third Place:	Thomas G. Gainer	B. T. Washington Middle School
Second Place:	Jonathan F. Gerhard	Yorktown High School
First Place:	David R. Derkits	Yorktown High School

ENGINEERING 'B'

Honorable Mention	Phillip B. Northam	Gildersleeve Middle School
Honorable Mention	Karl J. Runge	Fred D. Thompson Middle School
Third Place	Rex K. Min	Denbigh High School
Second Place	Stephen Lynn	New Horizons Governor's School for Science and Technology
First Place	Joshua H. McDermott	H. B. Woodlawn

ENVIRONMENTAL SCIENCE 'A'

Honorable Mention:	Liberty A. Boor	Radford High School
Honorable Mention:	Ryan J.S. Brewster	Gildersleeve Middle School
Honorable Mention:	Hope A. Clayburn	Huguenot High School
Third Place:	Kimberly B. Beckerdite	Gildersleeve Middle School
Second Place:	Panagiotis T. Boudouvas	Washington-Lee High School
First Place:	Theodore M. Barnhill, III	Thomas Jefferson High School for Science and Technology

ENVIRONMENTAL SCIENCE 'B'

Honorable Mention:	Daria J. Farassat	New Horizons Governor's School for Science and Technology
Honorable Mention:	Heidi L. Hanneman	Yorktown High School
Honorable Mention:	Jennifer R. Hardy	Lee-Davis High School
Third Place:	Lale D. Gokbudak	Roanoke Valley Governor's School for Science and Technology
Second Place:	Matthew G. Gilman	Patrick Henry High School
First Place:	F. Bruce Furrow	Dinwiddie County High School

ENVIRONMENTAL SCIENCE 'C'

Honorable Mention:	Karen R. Leigh	Gildersleeve Middle School
Third Place:	Anna M. Heuhsen	The Collegiate Schools
Second Place:	Mary C. Knight	Yorktown High School
First Place:	Adrienne L. Huston	McLean High School

ENVIRONMENTAL SCIENCE 'D'

Honorable Mention:	Rachelle N. Ornan	Central Virginia Governor's School
Honorable Mention:	Julie K. Petho	Yorktown High School
Third Place:	Lawrence A. Morrison, Jr.	Wakefield High School
Second Place:	Bradley T. Messmer	Menchville High School
First Place:	Robin J. Rosenfeld	Thomas Jefferson High School for Science and Technology

ENVIRONMENTAL SCIENCE 'E'

Honorable Mention:	Brian T. Whitley	Patrick Henry High School
Honorable Mention:	Stacy L. Williamson	Central Virginia Governor's School
Third Place:	Jesse J. Spencer	Dozier Middle School
Second Place:	Stefany M. Tweed	Patrick Henry High School
First Place:	Cynthia Squires	Cave Spring High School

GENETICS AND CELLULAR BIOLOGY

Honorable Mention:	Ellen K. Daugherty	Wakefield High School
Honorable Mention:	Wendy G. Dillard	Roanoke Valley Governor's School for Science and Technology
Honorable Mention:	Jennifer E. Stevens	Yorktown High School
Third Place:	Carol A. Cocker	Yorktown High School
Second Place:	F. Bruce Furrow	Dinwiddie County High School
First Place:	Kenyatta Y. Lee	Richmond Community High School

MATHEMATICS AND STATISTICS

Honorable Mention:	David E. Bradley	Denbigh High School
Honorable Mention:	Jeffrey S. Ford	Craig County High School
Honorable Mention:	Kristin M. Joslyn	Kempsville High School
Third Place:	Keun-young Kim	Woodberry Forest School
Second Place:	Herbert M. Bedingfield	Woodberry Forest School
First Place:	Mark W. Lucianovic	Thomas Jefferson High School for Science and Technology

MEDICINE AND HEALTH 'A'

Honorable Mention:	Angela Brasseur	New Horizons Governor's School for Science and Technology
Honorable Mention:	Jenny J. Choi	New Horizons Governor's School for Science and Technology
Honorable Mention:	Domin Chung	Thomas Jefferson High School for Science and Technology
Third Place:	Caroline M. Carden	Kempsville High School
Second Place:	Rene' D. Elms	Yorktown High School
First Place:	Christopher R. Pyke	Yorktown High School

MEDICINE AND HEALTH 'B'

Honorable Mention:	Meghan E. Hamm	Liberty Middle School
Honorable Mention:	Alexander T. Hawkins	Swanson Middle School
Honorable Mention:	Stephen Kohlman	B. T. Washington Middle School
Third Place:	Aga J. Lewelt	Monacan High School
Second Place:	William H. McKee, III	Denbigh High School
First Place:	Griffin M. Weber	Dozier Middle School

MICROBIOLOGY 'A'

Honorable Mention:	Matthew C. Gracey	Gildersleeve Middle School
Third Place:	Sara E. Mallory	Patrick Henry High School
Second Place:	Gregory J. Furrow	Swanson Middle School
First Place:	Erica L. Balmer	Prince George High School

MICROBIOLOGY 'B'

Honorable Mention:	Amy E. Martin	Patrick Henry High School
Honorable Mention:	Mukul S. Nerurkar	Thomas Jefferson Middle School
Honorable Mention:	Joseph K. Warren	Episcopal High School
Third Place:	Erin P. Sikes	Wakefield High School
Second Place:	Jeffrey J. Scarano	Yorktown High School
First Place:	Kristin P. Walinski	Patrick Henry High School

PHYSICS 'A'

Honorable Mention:	Alexander V. Agranov	Thomas Jefferson High School for Science and Technology
Honorable Mention:	Benjamin L. Barry	Swanson Middle School
Honorable Mention:	Gerard T. Hopkins, III	Yorktown High School
Third Place:	Jesse S. Chawla	Menchville High School
Second Place:	Erik T. Brandsberg	Central Virginia Governor's School
First Place:	Tyler F. Gray	Yorktown High School

PHYSICS 'B'

Honorable Mention:	David K. Messmer	Homer L. Hines Middle School
Honorable Mention:	Andrew R. Parker	Wakefield High School
Honorable Mention:	Elizabeth A. Pleasants	B. T. Washington Middle School
Third Place:	Ronald A. Northrip	Washington-Lee High School
Second Place:	Julie P. Houghton	Cave Spring High School
First Place:	Bradley T. Messner	Denbigh High School

PHYSICS 'C'

Honorable Mention:	Richard H. Singleton	Lee-Davis High School
Honorable Mention:	Lloyd A. Taylor	Radford High School
Honorable Mention:	Jeffrey S. Wright	Patrick Henry High School
Third Place:	Heather L. Smart	Wakefield High School
Second Place:	Jane F. Watson	Patrick Henry High School
First Place:	Venkataramana K. Sadananda	Thomas Jefferson High School for Science and Technology

PSYCHOLOGY - GENERAL

Honorable Mention:	Kristen M. Bersticker	Kempsville High School
Honorable Mention:	Matt S. Daimler	Gildersleeve Middle School
Honorable Mention:	Claire A. Homan	Yorktown High School
Third Place:	Joanne P. Dixon	Lee-Davis High School
Second Place:	Katrina E. Anderson	Yorktown High School
First Place:	Carrie A. Woods	Roanoke Valley Governor's School for Science and Technology

PSYCHOLOGY - LEARNING AND PERCEPTION 'A'

Honorable Mention:	R. Elizabeth Barker	John Handley High School
Honorable Mention:	Lisa M. Conge	Bishop Denis J. O'Connell High School
Honorable Mention:	Shelly R. Fisher	Radford High School
Third Place:	Mary H. Jenczewski	Midlothian High School
Second Place:	Julia B. Brown	Richmond Community High School
First Place:	Jeremy R. Jenkins	Matoaca High School

PSYCHOLOGY - LEARNING AND PERCEPTION 'B'

Honorable Mention:	David J. Kistner	Roanoke Valley Governor's School for Science and Technology
Honorable Mention:	Lynne F. Pruszkowski	Yorktown High School
Honorable Mention:	Brooke Wily	Clover Hill High School
Third Place:	Patricia A. Spruill	Yorktown High School
Second Place:	James E. Turner, III	Roanoke Valley Governor's School for Science and Technology
First Place:	Anne R. Nester	Yorktown High School

PSYCHOLOGY - SOCIAL

Honorable Mention:	Erin E. Holsinger	Yorktown High School
Honorable Mention:	Mary Lynn F. Jones	Yorktown High School
Honorable Mention:	Trang M. Nguyen	Meadowbrook High School
Third Place:	Paul E. Nguyen	Washington-Lee High School
Second Place:	April L. Umminger	Wakefield High School
First Place:	Kathleen A. Deuel	Kenmore Middle School

SPACE SCIENCE

Honorable Mention:	William H. Brown, III	Central Virginia Governor's School
Honorable Mention:	Tim Hobbs	Williamsburg Middle School
Honorable Mention:	Jennifer L. Thompson	William Fleming High School
Third Place:	David N. Christian	Newsome Park Middle School
Second Place:	Heather L. Stevens	Yorktown High School
First Place:	Kevin B. Jones	Washington-Lee High School

ZOOLOGY 'A'

Honorable Mention:	Jeffrey W. Binsley	Lee-Davis High School
Honorable Mention:	John P. Herald	Meadowbrook High School
Honorable Mention:	Sarah L. Hill	Central Virginia Governor's School
Third Place:	Yanek G.D. Korff	Swanson Middle School
Second Place:	Cara A. Gwinn	Matoaca High School
First Place:	Wendy A. Lee	Menchville High School

ZOOLOGY 'B'

Honorable Mention:	Kristen M. Mansfield	Dinwiddie County High School
Honorable Mention:	Siddhartha G. Shukla	Swanson Middle School
Third Place:	Jeffrey L. Stockwell	Patrick Henry High School
Second Place:	Sean M. Murray	Roanoke Valley Governor's School for Science and Technology
First Place:	Matthew K. Seidman	Washington-Lee High School

SPECIAL AWARDS

Roscoe Hughes Award for the best paper in the field of genetics (\$50.00)

Kenyatta Y. Lee
Richmond Community High School

Botany Section Award, given by the Botany Section of the VAS, to the best paper on a botanical subject.(\$50.00)

Laura M. Pottmyer
H. B. Woodlawn

VJAS Neuroscience Awards supported by the Auxiliary of the Virginia Neurological Society are given to four outstanding papers in the field of neuroscience.(\$50.00 each).

Anne R. Nester - Yorktown High School
Kristie L. Seymore -New Horizons Governor's School
for Science and Technology
William H. McKee, III - Denbigh High School

Richmond Area Speleological Society - (\$50.00)

Ernst H. Kastning, III
Radford High School

Mathematics Award for the paper that evidences the most significant contribution in the field of Mathematics.(\$50.00)

Mark W. Lucianovic
Thomas Jefferson High School for Science and Technology

Rodney C. Berry Chemistry Award for the paper that evidences the most significant contribution in the field of chemistry.(\$50.00)

Mark J. Gelman
Thomas Jefferson High School for Science and Technology

Russell J. Rowlett Award for the Best Research Paper of the Year.(\$50.00)

Venkataramana Sadananda

Thomas Jefferson High School for Science and Technology

The Virginia Psychological Foundation Meritorious Research Awards recognize outstanding presentations of research in the various fields of psychology. Each award includes a prize of \$70.00. Dr. James P. O'Brien will present this year's honors on behalf of the Virginia Psychological Foundation to:

Kathleen A. Deuel - Kenmore Middle School

Anne R. Nester - Yorktown High School

Jeremy R. Jenkins - Matoaca High School

Carrie A. Woods - Roanoke Valley Governor's School
for Science and Technology

American Cancer Society Award - This award is to recognize outstanding science papers related to cancer research. A certificate to each and to 1st place - \$200, 2nd place \$150, 3rd place \$100, and Honorable Mention \$50. The local chapters of the American Cancer Society will also present a plaque to each in the fall. Dr. Richard Brandt, Professor of Biochemistry, MCV/VCU who is the President of the Virginia Academy of Science and the Public Education Chairman, Richmond Division of the American Cancer Society will present the awards funded by the State Public Education Committee of the American Cancer Society.

Honorable Mention - (\$25 or \$50)

	Kenyatta Y. Lee	Richmond Community High School
Third Place - (\$100)	Susan R. Busic	Patrick Henry High School
Second Place - (\$150)	Cynthia Squires	Cave Spring High School
First Place - (\$200)	Bradley T. Messmer	Menchville High School

Trip to AJAS - AAAS Meeting for two students and two alternates for presenting outstanding papers

Griffin M. Weber - Dozier Middle School

Kristen Walinski - Patrick Henry High School

Alternate: Mark Gelman - Thomas Jefferson High School
for Science and Technology

Alternate: Anne R. Nester - Yorktown High School

Bethel High School Scholarship

This \$1,000 Scholarship Award comes from the interest earned from a \$10,000 endowment contributed by the students of Bethel High School, Hampton, Va., over a two year period. Accompanying this scholarship is a rotating plaque to be displayed in the student's school for the next year. This award is based on both the students presentation and paper.

Kenyatta Y. Lee
Richmond Community High School

Frances and Sydney Lewis Environmental Scholarship

An \$11,500 scholarship (\$2,875 per year for four years) for the best effort by a student grades 9 to 12 in the field of environmental science. This scholarship is in the name of Frances and Sydney Lewis and is given by the Virginia Environmental Endowment

Robin J. Rosenfeld
Thomas Jefferson High School for Science and Technology

The Editor has agreed to publish these abstracts of papers presented during the 1990 academy meeting held at George Mason University. In the future, late abstracts will not be accepted.

Environmental Sciences

SUBSURFACE MICRO-IRRIGATION OF ROW CROP IN VIRGINIA. Norris L. Powell, Dept. of Crop & Soil Environ. Sci., Tidewater Agricultural Experiment Station, VPI & SU, Suffolk, VA 23437, and F. Scott Wright*, Tidewater Agricultural Experiment Station, USDA-ARS, Suffolk, VA 23437. By burying micro-irrigation tubing fourteen to sixteen inches below the soil surface a row crop such as corn and peanut can be easily irrigated. When compared with overhead sprinkler irrigations this offers the advantages of more efficient use of water, lower labor requirement, lower energy requirements, more efficient use of water, ease of automation, reduced water runoff (from irrigation) reduced soil erosion (caused by irrigation) and the system can be phased in overtime. Initial investment cost varies with the distance between the micro-irrigation tubing lines buried below the crop and is equal to or higher than center pivots utilizing the full circle or the hose tow traveling guns. Operating cost is one-half (medium pressure center pivot) to one-fifth (hose tow traveling gun) of the cost of the overhead sprinkler systems. Between 1986 and 1989 corn yields were increased by five (1989) to 384 percent (1987) with the use of subsurface micro-irrigation when compared with no irrigation. For peanut the yield increases were nine (1986) to 18 percent greater with the use of subsurface micro-irrigation when compared with no irrigation. A permanently installed subsurface micro-irrigation system should last longer than 10 years with proper management.

Statistics

RELATIONSHIPS BETWEEN A SURVIVAL MODEL AND LOGISTIC REGRESSION: EXAMPLES IN MODELING OUTCOMES OF MEDICARE DATA. R. Clifton Bailey, Statistical Advisor, Health Standards and Quality Bureau, ME 2-D-2, Health Care Financing Administration, 6325 Security Blvd., Baltimore, MD 21207. In the HCFA publication, Hospital Mortality Information, a logistic regression was used to risk adjust the mortality status of medicare beneficiaries 30 days post admission. In an effort to develop a more informative evaluation of mortality status, I have investigated the use of survival models to characterize the mortality status of patients over time. This presentation will review the background of the problem and demonstrate some useful relationships between survival models and logistic regression. Methods will be demonstrated for using logistic regression to evaluate a survival model for a specific time post admission. Furthermore, as a byproduct of the evaluation one obtains polishing factors which can be used to fine tune a survival model for a specific time. Furthermore, it is shown that the survival model with concomitant variables can be used to estimate the equivalent coefficients for a logistic regression. Also, results relating predictions for average values of concomitant variables with the results of averaging individual predictions are presented.

EARTHQUAKES AND THE EXPONENTIAL PROBABILITY DISTRIBUTION.

Charlotte Blair, W. Michael Gentry, and Susan Zabel. Mary Baldwin College, Staunton, VA. On October 17, 1989, an earthquake measuring 6.9 on the Richter scale devastated sections of San Francisco. It is difficult to prepare for earthquakes, since they are basically random phenomena, but valuable information is gained by studying their seismic history and the time between earthquakes. Parkfield is located on the San Andreas Fault approximately midway between Los Angeles and San Francisco. Earthquakes occurred in Parkfield in 1857, 1881, 1901, 1922, 1934, and 1966. From these data, it is possible to compute the mean time between earthquakes, and then use the Exponential distribution to compute the probability of an earthquake occurring within a specified period of time. Although the use of the Exponential distribution represents an idealization of the problem at hand, the knowledge gained is valuable.

SAMPLING PROBLEMS IN PRE-ELECTION POLLS. A. Richard Bolstein, Center for Computational Statistics, George Mason University, Fairfax, Virginia 22030. A 1988 validated presidential pre-election poll of registered voters in a small city was used to compare the likelihood to vote among the respondent and various non-respondent groups, to predict the likelihood to vote of individual respondents, to compare different bases of respondents as predictors of the election outcome, and to estimate the effect of non-respondents and undecided respondents on the prediction. A 1989 validated pre-election poll was also conducted using the respondents from the 1988 poll to predict the outcome of the Virginia gubernatorial election. The impact of the abortion and racial issues on the outcome are discussed.

TESTS OF HYPOTHESES BASED ON RANKS IN THE STANDARD MULTIVARIATE LINEAR MODEL. Enoch B. Bortey, Dept. of Biostat., Va. Commonwealth Univ., Richmond, Va. 23298-0032. A unified approach is developed for testing hypotheses in the standard multivariate linear model based on the ranks of the residuals. Hypotheses concerning a subset of specified parameters can be tested, while the remaining parameters are treated as nuisance parameters. Asymptotically, the test statistic is shown to have a chi-square distribution under the null hypothesis. This result is then extended to cover a sequence of contiguous alternatives from which the Pitman efficacy is derived. The general application of the test requires the consistent estimation of a functional of the underlying distribution and one such estimate is furnished.

MEASURES OF PROBABILITY JUDGMENT PERFORMANCE: THE PROBLEM OF ACCURACY IN SOCIAL PERCEPTION AND PREDICTION. Susan E. Brodt, Darden Graduate School of Business, Univ. of Va., Charlottesville, Va. 22906-6550. Traditional measures of probability judgment performance used to verify forecasts about events in the physical domain (e.g., weather forecasts) offer both opportunities and pitfalls for scientists studying social judgment and prediction. Measures such as the Brier score and its various decompositions (e.g., calibration, resolution, reliability-in-the-small), provide statistical rigor and insight into the study of social cognition. Researchers' attention shifts away from problems of criterion verification and reliance on outcome accuracy, toward examination of the external validity of one's beliefs or the appropriateness of one's confidence in his/her knowledge. Ironically, if social scientists overlook methodological and statistical requirements and de facto definitions of accuracy these measures employ, one potential liability may be inevitable—judgmental overconfidence. Sources of benefit and potential cost are discussed.

STRONG MODERATE DEVIATION THEOREMS FOR m -DEPENDENT RANDOM VARIABLES. Narasinga Rao Chaganty, Dept. of Mathematics and Statistics, Old Dominion University, Norfolk, Va. 23529. Consider a stationary sequence $\{X_n, n \geq 1\}$ of m -dependent random variables. Let $S_n = \sum_{i=1}^n X_i$ be the partial sum. Under some moment conditions, we asymptotic expressions for the probability of moderate deviations, $P(S_n > x_n)$, where $x_n = O(\sqrt{\log(n)})$. These extend some well known results for independent and identically distributed sequences of random variables.

A PARTIALLY-WEIGHTED GENERALIZED MULTIVARIATE ANALYSIS OF VARIANCE MODEL. Vernon M. Chinchilli, Dept. of Biostatistics, VA Commonwealth Univ., Richmond, VA 23298-0032, & Mary Hall Gregg, Merck Sharp & Dohme, Chaussee De Waterloo 1135, 1180 Brussels, Belgium. We examine the generalized multivariate analysis of variance model in terms of a partially-weighted analysis, in which we consider only a subset of the available covariates. We develop estimation and hypothesis testing for the partially-weighted model under multivariate normality, and we establish conditions under which the partially-weighted estimator is more efficient than the weighted and unweighted estimators. Also, we show that for an important subclass of general linear hypotheses, the test statistics are invariant to the choice of transformation matrix in the partially-weighted model. We propose a procedure for selecting an appropriate subset of covariates, which is based on an examination of likelihood ratio statistics from a best subsets regression and where each likelihood ratio statistic is a test of the independence of two multi-normal vectors. We provide a modification to multivariate data sets with missing values via estimated generalized least squares. Also, we indicate how a partially-weighted analysis is applicable to longitudinal data analysis or repeated measurements regression.

DISTRIBUTION-FREE TESTS FOR INTERACTION IN A TWO-WAY DESIGN. Tsui-Hsien (Joanna) Chien*, Dept. of Biostatistics, Va. Commonwealth Univ., Richmond, Va. 23298-0032. The usual test for interaction effect in a two-way layout is based on the assumptions of independence of the observations, constancy of variance and normality. When the assumptions do not hold, it is useful to have available other inferential procedures with less restrictive assumptions. In this paper, two distribution-free test statistics based on U-statistics are discussed. One measures the magnitude of the interactions while the other measures 'directional' interactions. There is an equivalent relationship between these two test statistics and both of them have asymptotic chi-square distributions. These two tests are shown to be consistent and the asymptotic relative efficiencies of them are also studied. At the end, a simulation study is conducted to investigate the relative performance of the tests with smaller sample sizes, and some numerical examples are presented.

METHODS FOR COUNTING RARE AND ELUSIVE POPULATIONS. Charles D. Cowan, Chief Statistician, Opinion Research Corporation, 500 E. Street, SW, Suite 940, Washington, DC, 20024. Statisticians often want to draw inferences regarding populations that are hard to find, ill-defined, or just elusive. Examples of such populations are the homeless, missing children, users of particular social services (such as agricultural giveaway programs), and migrant workers. At times, the populations are well defined but not readily observable because they are very rare and there is no register or list with which to locate them. An example would be persons with relatively rare genetic disorders. This presentation looks at four procedures for finding and enumerating rare populations: sampling, multiplicity techniques, multiple frame techniques, and multiple capture techniques. The models underlying each technique will be compared, and the costs and benefits of use of each technique will be explored. Some examples of studies will be given based on the author's experiences.

OUTLIERS AND INTERACTION-IS THERE A CONNECTION? Barbara R. Kuzmak and Eric P. Smith*, Dept. of Statistics, Va Polytechnic Inst., Blacksburg, VA 24061. Outliers and interaction are generated by different mechanisms. An outlier may be produced by a recording error, equipment failure, violation of model assumptions, etc., whereas an interaction is the result of a synergistic effect among several factors. Interaction reveals important knowledge about the system under investigation, but an outlier usually does not convey useful information. However, in a nonreplicated two-way analysis of variance, outlier effects appear as interaction. The additive plus multiplicative model, $Y_{ij} = \mu + \alpha_i + \beta_j + \sum \lambda_{ij} \tau_{ij}$, has been used to describe multiplicative interaction in an unreplicated experiment. We use this model in the same setting to study outliers. In data sets with significant interaction, one may be interested in determining whether the cause of the interaction is due to a true interaction, outliers or both. We developed a new technique which can show how outliers can be distinguished from interaction when there are simple outliers in a two-way table. Several examples illustrating the use of this model to describe outliers and interaction are presented.

ON THE OPTIMALITY PROPERTIES OF SETS OF YODEN DESIGNS. J. P. Morgan, Dept. of Math. & Stat., Old Dominion Univ., Norfolk, Va. 23529. A generalized Youden design $GYD(v, p, q)$ is a $p \times q$ row/column design for v treatments for which each of rows and columns forms a balanced block design. A GYD is regular if either p or q is a multiple of v , and otherwise is non-regular. That regular GYD's are universally optimum, and non-regular GYD's are A-, E-, and D-optimum, was shown by Kiefer (1975). Here some optimality properties of sets of GYD's are established when $b > 1$ $p \times q$ designs are to be used. In particular, in the regular case b GYD's are universally optimum, while in the non-regular case counterexamples are given to show that A- and D-optimality are lost. Some results on the E-behavior of $b = 2$ GYD's are also given.

ANALYSIS OF MISSING DATA UNDER NON-RANDOM MECHANISMS: BAYESIAN INFERENCE. Patricia A. Pepple, Department of Mathematical Sciences, Virginia Commonwealth University, Richmond, Va. 23284, & Sung C. Choi, Department of Biostatistics, Virginia Commonwealth University, Richmond, Va. 23298. Inferences are made concerning population proportions when data are not missing at random. Both one-sample and two-sample situations are considered with examples in clinical trials. The one-sample situation involves the existence of response related missing data in a study conducted to make inferences involving the proportion. The two-sample problem involves comparing two treatments in clinical trials when there exists nonrespondents due to both the treatment and the response to the treatment. Bayes procedures are used in estimating parameters of interest and testing hypotheses of interest in these two situations. An ad-hoc approach to the classical inference is presented for each of the two situations and compared with the Bayesian approach discussed. To illustrate the theory developed, data from clinical trials of severe head trauma patients at the Medical College of Virginia Head Injury Center from 1984 to 1987 is considered.

DIFFERENCES BETWEEN ATMOSPHERIC OZONE PROFILES DERIVED FROM OZONE SONDES AND THE SAGE I AND II SATELLITE INSTRUMENTS. Robert E. Veiga, S. T. Systems Corp., 28 Research Drive, Hampton, VA 23666. Ozone sonde profiles from 14 stations have been spatially and temporally colocated with satellite ozone profiles measured by SAGE I and SAGE II over the period 1979-1989. Estimates of difference profiles measured with respect to the satellite observations indicate three altitude dependent types of behavior. From 10-14 km the differences increase from values as small as -50% to large positive values ranging from 10-40%. A discontinuity exists in the difference profile at 14 km. From 15 km to the ozone density peak the satellite measurements are larger than the in situ measurements, peaking at 16 km with values ranging from -5% to -35%. From 16 km to the peak of the ozone density the relative differences decrease to zero. From the ozone maximum to 27 km there are no statistically significant differences. Above 27 km the ozone sonde values tend to be lower than the satellite measurements, a behavior consistent with sonde pump efficiency losses at low ambient pressures. Regression analyses using monthly means over an 11 year period from satellite data and observations from two specific ground stations were performed in order to contrast ozone trends. The results show that an ozone decrease occurred from 15-25 km.

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Utilization of Response Surface Modeling to Evaluate the Interaction between Aflatoxin B₁ and Caffeine on Egg-Adult Viability in *Drosophila melanogaster*.

David A. Bettinger and Joseph P. Chinnici

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Richmond, VA 23284-2012

ABSTRACT

Utilizing five different concentrations of aflatoxin B₁ (AFB₁) and caffeine, the effect of continuous larval exposure to AFB₁ and/or caffeine at all possible concentration combinations on egg-adult viability was determined for several wildtype strains of *Drosophila melanogaster*. The data were analyzed by ANOVA and Response Surface Methodology (RSM) using a beta (β) binomial model. RSM analyses were used to generate 3-dimensional plots visually predicting the interactions of the tested compounds at concentration combinations not actually tested. Analyses indicate that slightly to moderately toxic levels of caffeine dramatically reduce the toxic effect of AFB₁, and that the compounds interact synergistically to reduce lethality.

INTRODUCTION

Aflatoxins are oxygenated, heterocyclic secondary metabolites of some species of the fungus *Aspergillus*, often contaminating agricultural products such as peanuts, corn, cottonseed, tree nuts, and other crops not only in the field but also during harvesting, in storage, and during processing (Wood, 1989). Aflatoxins, particularly aflatoxin B₁ (AFB₁) are powerful mutagens and teratogens, as well as vertebrate hepatocarcinogens and hepatotoxins (Ong 1975, Wogan and Busby 1980). Human health effects apparently include liver cancer, though the association between aflatoxin in the diet and liver cancer is confounded by the incidence of hepatitis B virus (Yeh et al. 1989, Stoloff 1989). Aflatoxins are also toxic to invertebrates, including *Drosophila* (Kirk, et.al. 1971), with larval growth in media contaminated with AFB₁ leading to decreased viability, smaller pupal case and adult body lengths, and increased developmental times (Lalor, et.al. 1976).

Caffeine (1,3,7-trimethylxanthine), a natural metabolite of *Coffea* and other plant species, is neurogenic, mutagenic, and toxic to a number of species under certain conditions (Kihlman 1977, Tanzarella et.al. 1984). However, under other conditions, caffeine has the ability to protect cells and organisms to some extent from the adverse effects of other toxigenic agents (Kakunaga 1975, Nomura 1980, Nigsch et.al. 1977), including aflatoxin (Cramer and Painter 1981, Chinnici and Bettinger 1984.)

This study was undertaken to further characterize the interaction between AFB₁ and caffeine affecting egg-adult viability in *Drosophila melanogaster* by applying an analytical technique called Response Surface Methodology (RSM) to the viability data.

RSM is a multivariate method widely used in engineering, agronomy, and product development (Mead and Pike 1975); recently, the utility of RSM in toxicological studies has been demonstrated (Carter et.al. 1985). RSM involves development of mathematical models and equations that relate the biological response to the concentrations of the agents used. The models/equations indicate the relative importance of each agent in producing the biological response and permit the interpretation of the type (inhibitory, additive, or synergistic) and relative strengths of each agent involved in the interaction. In addition, RSM can predict the response that would occur if combinations of concentrations different from those investigated experimentally were used. In this study, RSM was used to determine the effects of AFB₁ and caffeine applied singly and in combination on egg-adult viability in *Drosophila*.

METHODS AND MATERIALS

Insects. Three wildtype strains of *D. melanogaster* were used: Lausanne-S (A-11), a standard laboratory strain obtained from the Mid-America *Drosophila* Center, Bowling Green OH, and strains 3B and 34, originally captured from Virginia localities in 1980 (Delawder and Chinnici 1983) and maintained by mass culture.

Chemicals and culture medium. The culture medium consisted of yeast, dextrose, agar and several inorganic salts, with tegosept added as a mold inhibitor. Control (no AFB₁ or caffeine) and stock solutions containing either 0.00, 0.16, 0.32, 0.48, or 0.64 X 10⁻⁵ M AFB₁ (Grade A, Calbiochem-Behring, LaJolla CA) alone, 0.0, 0.5, 1.0, 1.5, or 2.0 X 10⁻² M caffeine alone, and mixture of all pairwise combinations of AFB₁ and caffeine were produced. These were poured into a series of 8-dram shell vials (8 ml medium per vial), stoppered with foam plugs and refrigerated until used. All experiments were performed at 25 ± 1°C.

Experimental procedures. Flies from the three strains were allowed to lay eggs for 12 hr in half pint culture bottles containing control medium. The eggs were then collected, and groups of 25 were placed on small squares of moistened blotting paper. Each shell vial containing medium received one group of 25 eggs, and each of the 25 treatments was replicated six times. As the cultures developed, data were collected daily on egg-pupal and egg-adult viabilities and development times and adult body lengths (tip of head to tip of abdomen). Only the egg-adult viability data are reported here.

RSM analysis. The data were analyzed by Drs. Hans Carter and Vernon Chinchilli of the Department of Biostatistics at the Medical College of Virginia of Virginia Commonwealth University to determine a mathematical model that best approximates the observed relationships between levels of treatments and effects on viability. A beta (β) binomial model with the following equation provided the closest approximation to the observed results:

Expected (Y) = 1/[exp {- β₀ - β₁X₁ - β₂X₂ - β₁₁(X₁)² - β₂₂(X₂)² - β₁₂(X₁X₂)}]

where

Y is the dependent variable: proportion of eggs producing larvae that develop into adults

X₁ is one independent variable: concentration of AFB₁

X₂ is the other independent variable: concentration of caffeine

β_0 is the population parameter denoting the Y-intercept (i.e., percentage of egg-adult viability in the control treatment)

β_1 is the population parameter denoting the slope of the linear response curve associated with AFB₁ concentration

β_2 is the population parameter denoting the slope of the linear response curve associated with caffeine concentration

β_{11} is the population parameter describing curvature in the dose-response relationship associated with AFB₁ concentration

β_{22} is the population parameter describing curvature in the dose-response relationship associated with caffeine concentration

β_{12} is the population parameter describing the interaction between the independent variables (AFB₁ and caffeine)

The β coefficients are determined by the method of maximum likelihood (Williams 1975). Once the β coefficients are determined from a set of actual data, any values for X_1 and X_2 (within the ranges of concentrations used in the experiment) can be used to calculate expected Y values (egg-adult viabilities). The full array of Y values may then be plotted as a three-dimensional "response curve".

RESULTS

For strains A-11, 3B, and 34, respectively, Figures 1, 2, and 3 graphically represent the egg-adult viability data for the 25 treatments, replicated six times each, of adding various concentrations of AFB₁ and/or caffeine to the culture medium in which larvae were grown. Inspection of the graphs indicates the following general trends:

- (1) Viability decreases with increasing concentration of AFB₁ alone in the medium (compare the solid bars in each graph);
- (2) Viability decreases with increasing concentration of caffeine alone in the culture medium (compare the first set of bars in each graph);
- (3) Caffeine, at moderate concentrations ($0.5\text{--}1.5 \times 10^{-2}$ M), lessens the toxic effect of AFB₁ on viability (compare viabilities at various concentrations of caffeine for 0.00 and 0.48×10^{-5} M AFB₁ for strain A-11, or for 0.00 and 0.32×10^{-5} M AFB₁ for strain 34);
- (4) To some extent, AFB₁ lessens the toxic effect of caffeine on viability (for strain A-11, compare viabilities at 1.0 or 1.5×10^{-2} M caffeine at increasing concentrations of AFB₁).

The best fit β coefficients for the β binomial formulas were calculated from the raw data for each strain of *Drosophila*. The RSM β coefficients and statistics are presented in Tables 1, 2, and 3. For strain A-11 for instance, the β binomial formula is: Expected (Y) = $1 / [\exp \{ - (0.407) - (-3.217)X_1 - (0.674)X_2 - (14.288)(X_1)^2 - (-2.787)(X_2)^2 - (7.839)(X_1X_2) \}]$. Substituting all values for X_1 and X_2 within the actual concentration ranges used in the experiments, response surfaces were generated for each strain predicting the probabilities of survival (Y) for each combination of AFB₁ and caffeine concentrations. These response surfaces for strains A-11, 3B, and 34, respectively, are illustrated in Figures 4, 5, and 6.

DISCUSSION

The data from this study, showing that AFB₁ and caffeine each have increasingly deleterious effects on egg-adult viability as concentrations are increased, and that

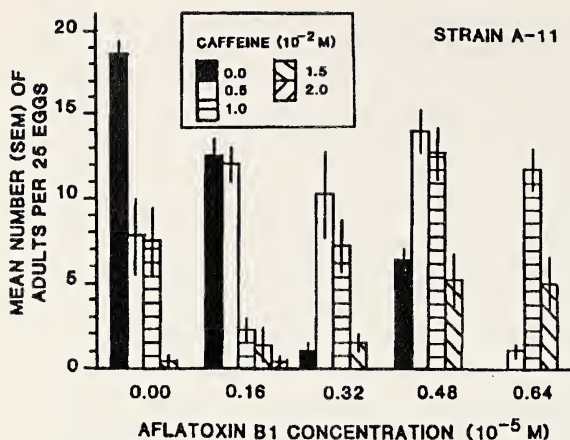


FIGURE 1. For strain A-11, numbers of adults (\pm standard error of the mean for six replications) that developed in vials initially containing 25 eggs and various concentrations of aflatoxin B1 and/or caffeine in the culture medium.

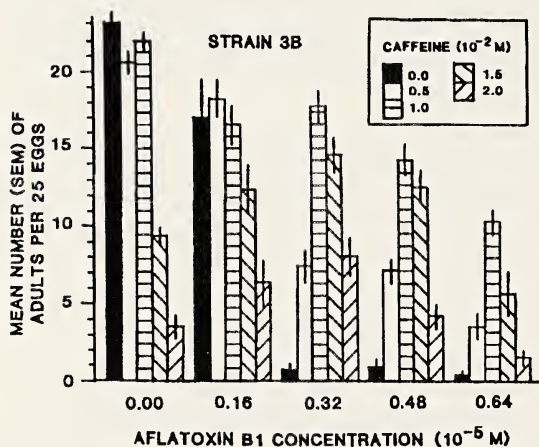


FIGURE 2. For strain 3B, numbers of adults (\pm standard error of the mean for six replications) that developed in vials initially containing 25 eggs and various concentrations of aflatoxin B1 and/or caffeine in the culture medium.

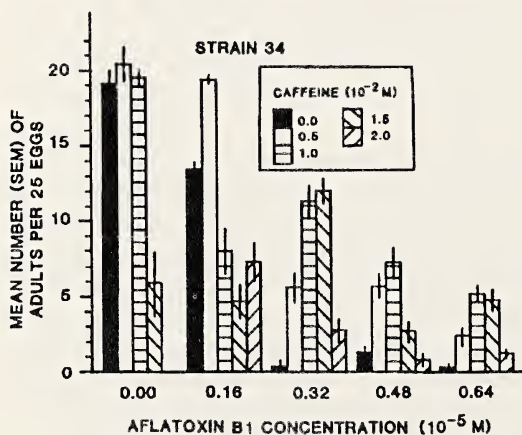


FIGURE 3. For strain 34, numbers of adults (\pm standard error of the mean for six replications) that developed in vials initially containing 25 eggs and various concentrations of aflatoxin B1 and/or caffeine in the culture medium.

TABLE 1. Beta coefficients and standard errors, as determined by least squares analysis, that best define the beta binomial formula for strain A-11. Results of chi square analyses, testing each beta coefficient against the null hypothesis that that the beta value is zero.

VARIABLE	BETA COEFFICIENT	STANDARD ERROR	CHI-SQUARE	P
Intercept	0.407	0.123	10.89	0.001
X ₁	-3.217	0.702	20.99	0.0001
X ₂	0.674	0.250	7.26	0.007
(X ₁) ²	-4.288	1.130	14.39	0.0001
(X ₂) ²	-2.787	0.184	229.04	<0.0001
X ₁ X ₂	7.739	0.539	211.09	<0.0001

TABLE 2. Beta coefficients and standard errors, as determined by least squares analysis, that best define the beta binomial formula for strain 3-B. Results of chi square analyses, testing each beta coefficient against the null hypothesis that that the beta value is zero.

VARIABLE	BETA COEFFICIENT	STANDARD ERROR	CHI-SQUARE	P
Intercept	1.330	0.135	96.54	<0.0001
X ₁	-7.155	0.673	113.05	<0.0001
X ₂	2.039	0.209	95.23	<0.0001
(X ₁) ²	-3.154	0.963	10.74	0.001
(X ₂) ²	-1.871	0.103	327.54	<0.0001
X ₁ X ₂	5.145	0.323	254.28	<0.0001

TABLE 3. Beta coefficients and standard errors, as determined by least squares analysis, that best define the beta binomial formula for strain 34. Results of chi square analyses, testing each beta coefficient against the null hypothesis that that the beta value is zero.

VARIABLE	BETA COEFFICIENT	STANDARD ERROR	CHI-SQUARE	P
Intercept	1.127	0.131	73.44	<0.0001
X ₁	-8.182	0.697	137.86	<0.0001
X ₂	1.263	0.222	32.30	<0.0001
(X ₁) ²	-0.943	1.060	0.79	0.373
(X ₂) ²	-1.619	0.117	192.02	<0.0001
X ₁ X ₂	4.873	0.370	173.51	<0.0001

the toxic effect is somewhat ameliorated when both agents are jointly administered corroborates previous work (Chinnici and Bettinger 1984). ANOVA of the previous data indicated that caffeine at moderate concentrations significantly reduced the toxic effects of AFB₁ on viability and developmental parameters. RSM analysis in this study has allowed the nature of the interaction to be more precisely defined.

The response surfaces depicted in Figures 4, 5, and 6 may be described by using an analogy. The three dimensions (X_1 , X_2 , and Y) describe a box. The vertical "walls" (Y axis) indicate the probability of survival. The "floor" has length (X_1 axis) and depth (X_2 axis). A sheet of paper, placed within the box on the floor, may be raised to various heights along the Y axis to indicate degree of viability associated with particular combinations of test agents. The front and left edges of the paper indicate viability levels due to AFB₁ alone (front edge) or due to caffeine alone (left side edge).

The β binomial equation provides a reasonably good approximation of the interactions of AFB₁ and caffeine as they affect egg-adult viability in *Drosophila melanogaster*. The β coefficients themselves provide information about the nature of the actions and interactions of the toxins. A positive β term for the cross-products (X_1X_2) variable indicates a synergistic (greater than additive) interaction between the test agents while a negative β term for the (X_1X_2) variable indicates an inhibitory interaction between the agents. For all strains studied, B_{12} is positive, indicating a synergistic interaction between AFB₁ and caffeine on viability (flies survive better when both are present than when either one alone is present).

The β coefficients of the X_1 and X_2 variables may be compared to determine the relative strengths of the X toxic agents regarding the response Y : the greater the β coefficient of an X variable, the more the X variable contributes to the response. For each strain tested, X_1 describes a negative slope and X_2 describes a positive slope. This indicates that caffeine has a much greater effect in protecting the larvae from the harmful effects of AFB₁ on viability than does AFB₁ in protecting larvae from harm due to caffeine.

Little is known about the biochemical effects of AFB₁ or caffeine ingestion in insects (Al-Adil et.al. 1973, Watson 1975, Foerster et.al. 1984), or about the interaction of these agents (Cramer and Painter 1981). In vertebrate systems, it is known that AFB₁ is activated by a type I, P-450 mixed function oxidase (MFO) to the toxic and reactive epoxide that binds to DNA, RNA, and protein macromolecules (Shepherd et.al. 1984, Kitada et.al. 1989, Shimada et.al. 1989). Detoxification mechanisms include conversion of the epoxide by an MFO into less toxic aflatoxin M, hydrolyzing the epoxide by an epoxide hydrolase, or conjugating the epoxide to glutathione S-transferase (Lotikar et.al. 1980, Shelton et.al. 1984). Elucidation of the mechanisms by which caffeine may inhibit the production of the AFB₁-epoxide and/or its binding to macromolecules, or may enhance epoxide metabolism awaits further investigation.

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STRAIN A-11

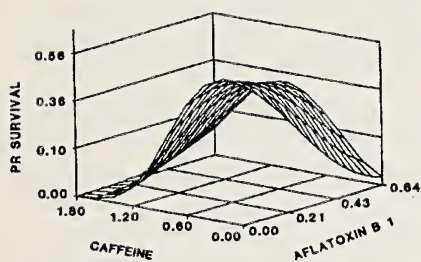
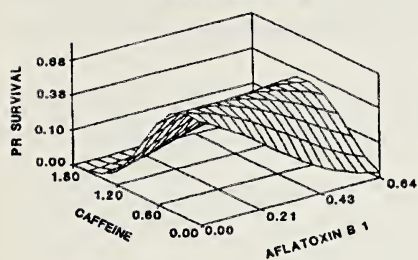


FIGURE 4. For strain A-11, the response surface generated by RSM for egg-adult viability at various concentrations of aflatoxin B1 and/or caffeine. Two views of the surface are shown. X1 axis = AFB1 concentrations, X2 axis = caffeine concentrations, Y axis = probabilities of eggs surviving to the adult stage.

STRAIN 3B

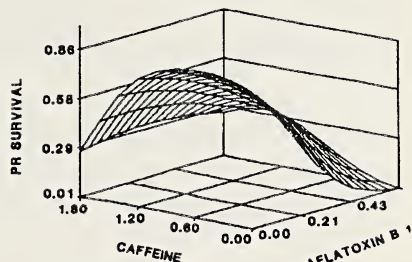
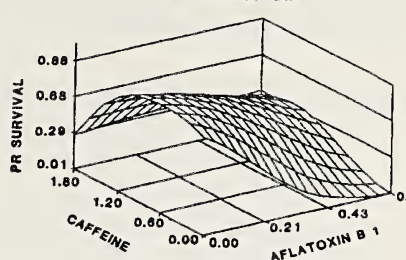


FIGURE 5. For strain 3B, the response surface generated by RSM for egg-adult viability at various concentrations of aflatoxin B1 and/or caffeine. Two views of the surface are shown. X1 axis = AFB1 concentrations, X2 axis = caffeine concentrations, Y axis = probabilities of eggs surviving to the adult stage

STRAIN 34

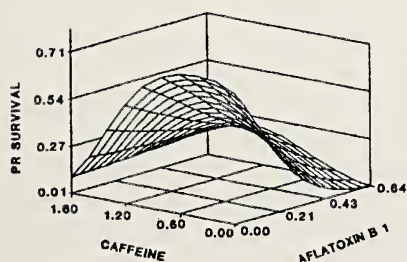
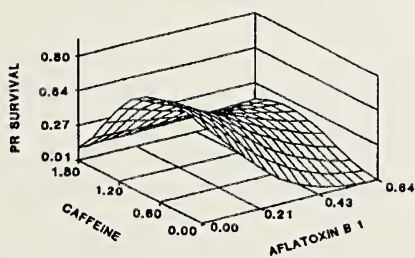


FIGURE 6. For strain 34, the response surface generated by RSM for egg-adult viability at various concentrations of aflatoxin B1 and/or caffeine. Two views of the surface are shown. X1 axis = AFB1 concentrations, X2 axis = caffeine concentrations, Y axis = probabilities of eggs surviving to the adult stage.

This paper is based on research performed by DAB as partial fulfillment of the MS in Biology requirements. JPC directed the project and prepared the manuscript.

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A Comparison Over Time of Two Virginia Populations of the Coquina Clam, *Donax variabilis*

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ABSTRACT

The coquina clam, *Donax variabilis*, is well known for its great variation in shell colors and patterns. This extensive polymorphism and a short life span make *Donax* an interesting organism for studies of genetic variation in natural populations. In order to assess the stability of the polymorphism, samples were collected over one growing season from two sites in Virginia Beach, VA, and compared for the distribution of shell lengths and for the frequencies of colors and patterns both within and between locations. Populations at the two locations differed in nearly all respects, both at any one time and in their patterns of change over time. The distribution of shell lengths indicated that length was related to the age of the clam and also to the colors and patterns of the shell. The frequencies of both shell colors and patterns differed at the two sites and changed over time in different ways.

Key Words: *Donax*, polymorphism.

INTRODUCTION

Species of *Donax* (Mollusca: Bivalvia), commonly known as coquina clams, are found on sandy beaches along the eastern and western coasts of the United States, on the coast of the Gulf of Mexico, and on many other warm-water beaches around the world (Wade, 1967; Leber, 1982). Their ideal habitat is the wash zone of a gently sloping beach, halfway between the high tide mark and the water's edge. In a favorable environment, populations of *Donax* have been observed to reach densities of over 20,000 clams per square meter. Such a population, in a strip 2 to 5 meters wide, extended with some interruptions for more than five miles along the beach (Coe, 1953). These clams have attracted the attention of several ecologists because of their ability to migrate up and down the beach with the stage of the tide (Turner and Belding, 1957; Leber, 1982) and because the continuous growth of their shells makes them suitable for size/age studies (Cerrato, 1980; Bayne and Newell, 1983; Wilbur and Owens, 1983).

Rates of Growth: Coe (1955) followed rates of growth as well as population densities in his study of the California Bean Clam, *Donax gouldi*. He determined that clams at one and two years of age averaged about 12 mm and 18 mm in length, respectively, and that their first spawning occurred at the age of one to one and a half years. In some years almost all breeding individuals died after the first spawning, while in other years most individuals survived to spawn in a second summer. The few individuals which survived to the third year were about 20 mm in length.

Wade, in his 1968 life history study of the West Indian beach clam, *Donax denticulatus*, collected data monthly on lengths of shells at two sites over a period of two years, the typical life span of the species. He found that the average shell length increased rapidly during the first seven months of life and then more slowly until the eleventh month. Thereafter, adults grew only when food supplies were abundant. The average rate of growth at one site was much greater than that at the other, and Wade concluded that the differences in the maximum sizes of clams on beaches in the West Indies resulted from this factor. Both Coe's and Wade's findings indicate that, when ample food is available, *Donax* species can grow throughout their life spans and that the rate of growth is specific to the site of the population.

In a study of two populations of *Donax variabilis* in Florida, Mikkelsen (1983, 1985) showed major differences in density, tidal migration patterns, and growth rates between the populations. He attributed these differences to dissimilarities in slope, wave action, and particle size between beaches and concluded that each population had site-specific characteristics.

Studies of Polymorphism: Shell colors of marine mollusks were once assumed to be controlled by the environment, but recent studies have shown that shell colors and patterns are often genetically determined. A polymorphism for shell color is under genetic control in the scallop *Argopecten* (Adamkewicz and Castagna, 1988), the snail *Cepaea* (Cain et al., 1960), and the blue mussel *Mytilus* (Innes and Haley, 1977; Newkirk, 1980), although the exact mechanism which produces shell colors has not been determined.

The possible adaptive value of such polymorphisms has seldom been investigated. Mitton (1977) for the mussel *Mytilus*, and Heller and Volokita (1981) for the snail *Xeropicta*, proposed that differences in color may influence an animal's internal temperature. Populations in warmer climates tend to have higher frequencies of banding and of white and other light colors which can reflect heat, while those living in cooler climates tend to have higher frequencies of darker colors, which enable the animals to absorb solar radiation faster (Cain et al., 1960; Cook and King, 1966; Jones, 1973).

Cain (1988) has also noted that bivalves which commonly live buried in sediments tend to be drably colored while those species which are occasionally or always exposed to light (and thus to both visual predation and solar heating) are often polymorphic for bright colors. Moment (1962) had *Donax* specifically in mind as a possible example of a genus whose extreme polymorphism was an adaptation to visual predators. Although *Donax* species do burrow in the sand, they are frequently exposed to light and to view as they migrate up and down the beach with the tides, and both absorption of solar heat and exposure to visual predators (Smith, 1975; Schneider, 1982) are potentially important to them.

Very few studies have compared frequencies of shell colors and patterns among populations of *Donax*. Mikkelsen's (1978) comparative study of *Donax variabilis* showed that the frequencies of colors were significantly different in two Florida populations. He found that the frequency of white shells was higher at the Gulf coast site, while the frequency of the darker forms was higher at the Atlantic coast site. He attributed the differences in the frequencies of colors to water temperatures, the Gulf of Mexico being warmer on average, and suggested that the

differences in frequencies of patterns were maintained by apostatic or reflexive selection as originally proposed by Moment (1962) and Clarke (1962).

Even rarer than studies of the frequencies of colors and patterns found on the outside of *Donax* shells are studies of frequencies of colors and patterns found on the inside. Adamkewicz (1989) compared both inner and outer shell characters, as well as shell lengths, in samples of *D. variabilis* taken at one time from four Atlantic coast sites in North Carolina. She found that mean shell lengths and the frequencies of various colors and patterns were significantly different among the sites but could not detect a consistent pattern of change. She attributed the differences among the samples to either the establishment of each population at a different time or to adaptation to the local environment.

The differences in the frequencies of colors and patterns among populations at different locations raises the question of whether the growth rates, colors, and patterns of shells also vary over time at one site. To answer this question, samples of *D. variabilis* were collected over one growing season from two beach sites with distinctively different physical characteristics. The frequencies over time of shell lengths, colors, and patterns were examined and compared within and between populations.

SAMPLING

Samples were collected periodically for one growing season, June through November, at two locations. After November, low water temperatures made sampling impractical. The first site was on the beach in front of the Ocean Island Motel at the entrance to Lynnhaven Inlet in Virginia Beach, VA. This site was inside the Chesapeake Bay, sheltered from the waves of the open ocean. Adequate samples were found there in June, the first month in which the site was visited, and from August to November, but virtually no clams were found there in July. The second site, visited for the first time in July, was located eight land miles southeast of Lynnhaven on the beach at the end of 33rd Street in the city of Virginia Beach. This site was on the ocean, exposed to more intense wave action. Samples were taken from this population from July to November, but the November sample was too small to be useful. Collections were always taken near the time of low tide. Animals might be found anywhere from the middle of the wash zone to below the water's edge under about 10 cm of water.

Sizes of samples collected ranged from 12 to 803 individuals, and the occasionally sparse populations made density determinations unfeasible. Animals were collected by scooping sand onto a 1 mm mesh and rinsing in the sea water. The sieve was capable of retaining individuals as small as 1.5 mm, although no individuals smaller than 3 mm were ever found. Each shell was cleaned and its left valve measured to the nearest millimeter. Then, using a system similar to that of Adamkewicz (1989), the shells were scored for five characters. For statistical analysis, it was usually necessary to pool several possible states of each character. The scoring system and pooling procedures were as follows:

1. Background (BKGD) was defined as the color on the outside surface of the shell. It could be purple, red, yellow, brown, or white (which is simply the absence of any pigment). For analysis, these colors were pooled into white versus any other color.

2. One to many concentric rings (RINGS), could be present on the outer surface of the shell. These rings probably formed when a clam's growth was interrupted by adverse environmental conditions (Gordon and Carriker, 1978; Crenshaw, 1980) and could be purple, red, yellow or the background color of the shell. If the latter, RINGS was scored as absent. Pooling was colored RINGS present versus absent.

3. Purple juvenile rays (PJR) were first defined by Mikkelsen (1978) as three thin, purple lines radiating from the umbo. If present, they were most conspicuous on small animals (3 to 5 mm), hence the term juvenile. Pooling was present versus absent.

4. The extent of purple pigment on the inner surface of the shell (INSIDE) ranged from a complete covering, through a partial covering, to one single posterior ray, and finally to a shell that was entirely devoid of pigment on the inside. It was pooled as present (any pigment present) versus absent (no pigment INSIDE the shell).

5. The shell's umbo (UMBO), the area between two sets of hinge teeth, could be distinctly colored with purple or red or it could show only the background color of the shell, in which case UMBO was scored as absent. Pooling was colored UMBO present versus absent.

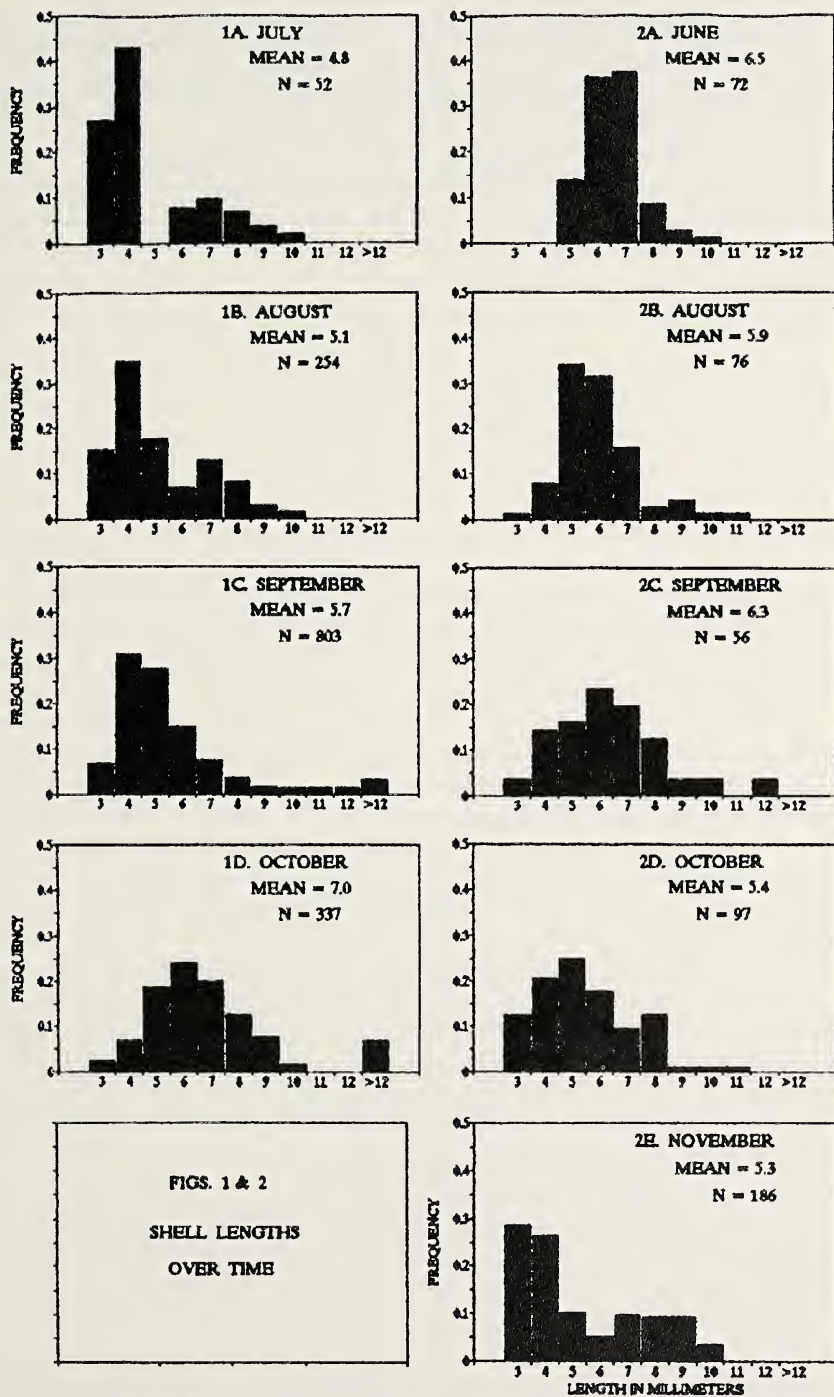
A total of 1,981 shells were examined: 1,482 from 33rd Street and 499 from Lynnhaven. During statistical analysis, the two samples with fewer than fifty individuals, November at 33rd Street and July at Lynnhaven, were simply dropped, and the first collections at the two sites were considered equivalent even though they were taken in different months. This treatment was judged to be superior to pooling successive months at one site because of the strong evidence for change over time. For data on the five patterns, using all possible variants for a character resulted in very small numbers for some categories. Numbers were therefore pooled as described above. Data were then analyzed with one-way analyses of variance to test means and contingency chi-squares to compare frequencies.

RESULTS

Shell Lengths: According to Chanley and Andrews (1971), *Donax* in the Virginia area complete their metamorphosis to the adult stage and begin settling into a population at about 3 to 4 mm in length, and the present results support their observation. Although smaller individuals could have been detected, the minimum shell length in any sample from either site was 3 mm.

The average shell length changed significantly over time at both sites, but the change was systematic and predictable only at 33rd Street, where, as expected during a growing season, the average shell length increased each month. A of one-way analysis of variance for each site showed that the mean lengths of shells in the samples from the four months were significantly different. A similar comparison showed that mean lengths for any one month were significantly different between the two locations.

Figures 1 and 2 present the distribution of shell lengths for the collecting period. Early in the period, the population at 33rd Street had more small, newly recruited individuals than large ones, while the Lynnhaven population lacked these very small individuals. Clearly both the pattern of change and the distribution of shell lengths differed at the two sites, and these differences may well be attributed to the time



FIGURES 1 and 2. The distribution of shell lengths in samples at 33rd Street from July through October (Figures 1a - 1d) and at Lynnhaven from June through November (2a - 2e). Means are in millimeters and N = Sample size.

TABLE 1. A summary of the results from one-way analyses of variance on shell lengths in different color/pattern variants each month at each site. Variants were pooled as described in the methods. No symbol indicates that the result was not significant, * denotes $p < 0.05$, ** denotes $p < 0.01$, and na denotes a test that could not be performed. For every significant test except those for UMBO, the colored variant had a larger mean than the uncolored one.

Character	33rd Street				Lynnhaven				
	J	A	S	O	J	A	S	O	N
BKGD	**	**	**						**
RINGS				**					**
PJR			**	**			*		*
INSIDE	**	**	**	**					*
UMBO	na	**	**	**					**

of recruitment for each site. Accepting the presence of 3-4 mm clams as evidence of recent recruitment, 33rd Street was adding new individuals primarily in July and August, and probably earlier, while recruitment in Lynnhaven occurred mostly September through November.

Figures 1 and 2 also provide evidence for a relationship between shell length and age. Figure 1a-d shows the distribution of shell lengths over time at 33rd Street. The earliest sample (Fig. 1a) lacked a 5 mm size class, dividing the lengths into two discontinuous ranges which were probably year classes or cohorts. The clams in the 6 to 10 mm size range were probably breeding individuals that survived the winter, while those in the 3 to 4 mm size range were probably new recruits into the population. Recruitment, then, would have had to begin at least two or three weeks earlier, in June.

The distributions in August (Fig. 1b) and September (Fig. 1c) had a continuous range of sizes from 3 to 10 mm and from 3 to 15 mm respectively. The appearance of larger size classes indicates growth, and the reduction in frequency with increasing size suggests that some of the larger clams were lost from the population through predation or death. A reduction in the frequencies of the two smallest size classes (3 to 4 mm) could also be seen, indicating that fewer new individuals settled into the population with each succeeding month.

In October, (Fig. 1d) the last month for samples from 33rd Street, the sample was again divided into two discontinuous size ranges, a small cohort that had survived from the previous year and a large cohort recruited earlier in the summer and now adult.

Figure 2a-e displays the distributions of shell lengths over time at Lynnhaven, which was very different from the pattern at 33rd Street. In June (Fig. 2a), Lynnhaven had a continuous range of sizes from 5 to 10. These individuals must have survived the winter, and recruitment into the population has not yet started for the year. August and September (Fig. 2b-c) showed evidence of some recruitment of new individuals and growth of adults. During October and November (Fig.

2d-e), recruitment increased and larger individuals began to be lost from the population.

Shell color and length: The relationship between shell color and shell length was examined within each population. For each month at each site, a one-way analysis of variance was used to compare the mean lengths of shells with and without each pattern, pooled as described in the methods section. A summary of the results is presented in Table 1. The effect of shell characters on mean length was much more pronounced at 33rd Street, where more than half of the statistical tests were significant, than at Lynnhaven, where fewer than a quarter of the tests were significant. All significant tests for every character except UMBO showed the mean to be larger for shells with more colors present.

Colors and Patterns: As shown in Figures 3 and 4, the frequencies of colors and patterns also varied over time within each population and differed between sites. Alternative states of each pattern were pooled as described in the methods section and a contingency chi-square was used to compare the frequencies of each shell character both month by month between sites and within each site over the collection period. These differences were always significant over time at any one site and were usually significant between sites for any one month. The test of UMBO for July/June between sites could not be performed because some of the expected frequencies were less than three. The remaining comparisons between sites showed that frequencies of colors and patterns were similar in the two populations during June/July and August but differed significantly between populations after that time.

Some characters such as RINGS, PJR, and INSIDE at 33rd Street showed systematic changes, increasing throughout the study period (Fig. 3), while other characters changed without apparent pattern. However, as shown in Table 2, every character changed significantly in frequency over time at each site.

DISCUSSION

The distribution of shell lengths over time in these Virginia samples confirms the pattern observed in *D. variabilis* in Florida (Mikkelsen, 1981 and 1985). As at other locations, growth continued throughout the life span, which was about one year. The samples collected from 33rd Street showed a steady increase in both mean length and size range, with the largest size class, 17 mm, appearing in October, indicating that the clams were growing continuously. Two distinct size classes for the sample collected in July at the 33rd Street site represented at least two age groups or cohorts, with the survival over the winter of older individuals and the input in the spring of new ones. The observation that the frequencies of larger size classes were always much lower than those of smaller sizes indicates continuous growth with mortality at the larger sizes. This fact, along with the absence of clams larger than 10 mm at both sites in the beginning of the collecting period, suggests that larger clams must have died during the winter or after an early spawning in the spring.

The results of this study also demonstrate that, when sampling populations of *Donax*, both the location and the time of year are important. Comparisons should be made between locations only with great care and based only on data covering extensive periods of time, because the pattern of growth and recruitment is not the

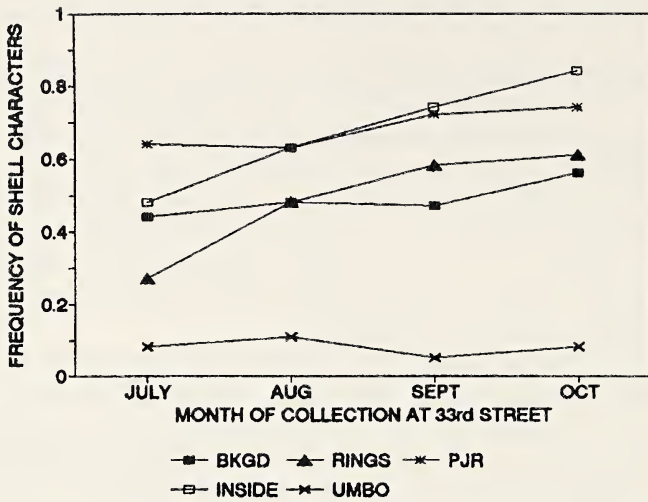


FIGURE 3. The frequencies of five shell characters in the samples from 33rd Street. Variants were pooled as described in the methods section and the values graphed are always for the colored variants as follows: BKGD, any color except white; RINGS, present; PJR, present; INSIDE, present; and UMBO, present.

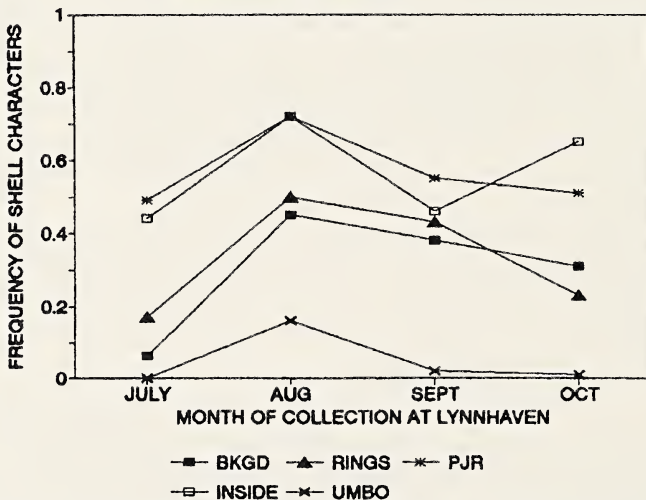


FIGURE 4. The frequencies of five shell characters in the samples from Lynnhaven. Variants were pooled as described in the methods section and the values graphed are always for the colored variants as follows: BKGD, any color except white; RINGS, present; PJR, present; INSIDE, present; and UMBO, present.

same at all locations. The contrast between the distribution of lengths at 33rd Street and the distribution at Lynnhaven showed that, while length was always a fair indicator of age, the association of a particular length with a particular age was site-specific. Clams at both sites showed continuous growth and mortality at larger sizes, but clams at Lynnhaven never reached as large a maximum length as clams at 33rd Street, and recruitment initiated much later at Lynnhaven.

The frequencies of the various polymorphic traits were also both time and site-specific, which will complicate efforts to discover the mechanism(s) that maintain the variation. The data cannot with certainty identify any one factor, but maintenance of the polymorphism for shell colors and patterns may depend at least in part on a mechanism already believed to act on the shells of other mollusks. Mitton (1977) proposed for the mussel *Mytilus edulis*, and Heller and Volokita (1981) proposed for the freshwater snail *Xeropicta*, that differences in color might affect the internal temperature of animals. Part of their evidence was that shells of animals in cooler climates had higher frequencies of darker colors, which would

TABLE 2. A summary of the results from the contingency chi-square analyses comparing the frequencies of the shell characters by site for any one month and by month for any one site. Variants were pooled as described in the methods. No symbol indicates that the result was not significant, * denotes $p < 0.05$, ** denotes $p < 0.01$, and na denotes a test that could not be performed. Actual frequencies over time are shown in Figures 3 and 4.

Character	SAME	SITE	SAME MONTH			
	33rd	Lynn	J	A	S	O
BKGD	*	**	**			**
RINGS	**	**			*	**
PJR	*	**			*	**
INSIDE	**	**			**	**
UMBO	*	**	na			*

enable the mollusks to absorb solar radiation more readily. In *Donax*, which are exposed to the direct sun as they migrate with the tides, the addition of colors to the shell might allow the clams to accumulate and retain a higher body temperature, which in turn would allow them remain active and grow longer as water temperatures cooled.

The evidence is compatible with this possibility. As mean shell length increased over time at 33rd Street, so did the frequencies of colored shells, which would be predicted by the theory. The majority of shells at both sites had a colored BKGD, and the addition of the other characters (UMBO, RINGS, INSIDE, and PJR) to the colors of BKGD darkened the appearance and potentially increased the heat retention of the shell. The frequencies of all these shell patterns (except UMBO, which was rare but fairly constant) showed a steady increase over the four months of the collecting period at 33rd Street. The frequencies of colored shells also increased overall, but not steadily, at Lynnhaven. It was not possible from our data to determine directly whether colored shells grew faster than uncolored ones, but increases in the frequency of colored shells coincided with periods of increased growth, and this fact argues that they do.

An alternative explanation would be that shells simply add more pigments as they grow larger. Shell colors and patterns do develop and intensify in larger clams (presumably as the shell grows), and this relationship probably accounts for at least part of the association between shell color and increased length. It cannot be a complete explanation because, in any one sample, colored shells were usually significantly larger than uncolored ones even in samples (e.g. November at Lynnhaven) where the overall average shell length was small.

The differences observed between 33rd Street and Lynnhaven in mean shell length, in the frequencies of colors and patterns, and in recruitment times, are consistent with studies done by Mikkelsen on *D. variabilis* in Florida (1981, 1985) and by Wade (1967, 1968) on *D. denticulatus* in Jamaica. Both investigators found differences in samples taken from different sites, and both attributed these differen-

ces to environmental factors: the slope of the beach, the nature of the sand, and/or the wave action.

The two locations in the present study have several striking environmental differences. The 33rd Street site is located on the open ocean, while Lynnhaven is just inside the Chesapeake Bay in a much more protected situation. The wave action at Lynnhaven is usually gentle and slow compared to that at 33rd Street. While the slopes of the two beaches are both gentle, the sand is coarser at Lynnhaven and the condition of the beaches is not the same. Debris accumulates both along the beach and in the water at Lynnhaven, in contrast to the beach at 33rd Street, which is comparatively clean. Although no single environmental factor can be associated with any specific difference between the populations, the typical habitat of *Donax* in the wash zone suggests that the difference in exposure to the surf is probably critical. A systematic comparison of populations in sheltered versus highly exposed locations would be of great interest.

Other important questions also await study. Recruitment patterns in the two populations are different, and we need to know both where new recruits originate and whether the patterns of recruitment remain the same from year to year. The polymorphism of the shells was not constant over the study period; shells changed in appearance as they grew. We need to know whether this cycle of changes is repeated each year. Finally, it is important to discover which environmental factors are influencing the lengths, colors, and patterns of these shells.

ACKNOWLEDGEMENTS

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An Anharmonic Oscillator

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ABSTRACT

A uniform sphere bobbing in water furnishes an example of an anharmonic oscillator. The motion of the sphere is compared with the oscillation of a block of constant cross section which also floats in water. The period of the bobbing sphere is obtained as an elliptic integral. Projects and problems which follow from a study of the bobbing sphere are appropriate in applied mathematics and in intermediate level mechanics.

INTRODUCTION

Some time ago, our attention was caught by an exercise in numerical integration. The problem was to evaluate a definite integral for the period of oscillation of a sphere as it bobs while floating in water (Shampine and Allen). Since the integral formula was given without derivation, we decided to derive the formula for ourselves.

After we had finished, the derivation seemed at least as interesting as the original exercise. Therefore, after looking at the bobbing of a block of constant cross section, we shall give a derivation of the formula for the period of the bobbing sphere in the case that the density of the sphere is one half that of water.

THE BOBBING BLOCK

The bobbing in water of a wooden block of uniform density and constant horizontal cross section is almost simple harmonic. That is, if we ignore the viscosity of the water, the equation of motion of the block takes the form $\ddot{y} = -\omega^2 y$. We assume that the amplitude of vibration is not so large that the top of the block will ever be submerged.

Let A denote the area of a cross section of the block taken parallel to the surface of the water and ρ ($0 < \rho < 1$) denote the specific gravity of the block. In Figure 1, we show the block with instantaneous water line at a vertical height y above the equilibrium level. The meaning of a positive value of y is that the block has been depressed from its floating rest position by a vertical distance y .

With Archimedes' Principle, we can find the buoyant force acting on the block. Then the unbalanced downward force (F) on the block as shown is its own weight minus the buoyant force which is just the weight of the displaced water. The volume of the block is Ah where h is height of the block. Since the density of water is 1 gm/cm^3 and the specific gravity of the block is ρ , the mass and weight of the block become ρAh and $g\rho Ah$, respectively. The volume and mass of the displaced water have the same numerical value, implying an upward force of $g\rho Ah + gAy$ due to buoyancy.

From Newton's Second Law, we can write the equation of motion for the block as

$$F = \rho Ah\ddot{y} = g\rho Ah - (g\rho Ah + gAy) = -gAy. \quad (1)$$

The term on the far right of the extended equation is negative because the net force is a restoring force in direction opposite to the displacement. An analysis of the

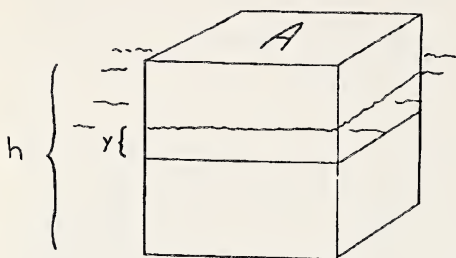


FIGURE 1. The bobbing block.

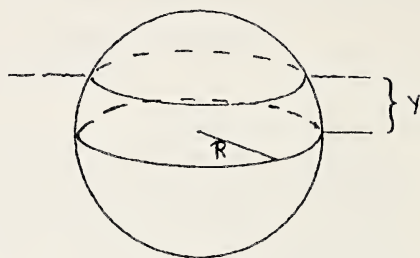


FIGURE 2. The bobbing sphere.

motion when the block has been raised with respect to the water level also yields a restoring force and the equation of motion is again given by 1. We now recognize this equation to be the standard equation of simple harmonic motion: $\ddot{y} = -\omega^2 y$ with $\omega^2 = g/(\rho h)$.

Rewriting this differential equation as $\dot{y}(d\dot{y}/dy) = -\omega^2 y$ permits us to integrate both sides to obtain

$$\dot{y}^2 = \omega^2 y_0^2 - \omega^2 y^2 \quad (2)$$

where y_0 is the value of y when $\dot{y} = 0$. It is easy to see that $y = y_0 \sin(\omega t + \delta)$ satisfies Equation 2. We have taken the trouble to give the equation because we will encounter an analogous equation when we derive the period of the bobbing sphere.

THE BOBBING SPHERE

Let us suppose that a sphere of radius R floats half submerged in water. That is, the specific gravity of the sphere is 0.5 and the center of the sphere is at the level of the water whenever the sphere floats in equilibrium. Let us next imagine that the sphere is pushed down until its center is a vertical distance q ($0 \leq q \leq R$) below the surface of the water. Then the sphere is released. In computing the period of the resulting motion, we shall ignore all effects due to friction and viscosity.

Unlike the block of constant cross section, the oscillating sphere does not displace a volume of water which is linearly proportional to its displacement. However, let us note that, for very small vertical displacements from equilibrium, the cross sections of the sphere at the water level do vary so slightly that the motion will approximate simple harmonic motion in the way the simple pendulum does for small angular displacements.

Consider the sphere when its center is at the depth y below the surface of the water. Then the volume of water displaced by the sphere (beyond its equilibrium displacement of $(2/3)\pi R^3$) is given by $\int_0^y \pi(R^2 - y^2/3) dy = \pi(R^2 y - y^3/3)$, and the weight of this displaced water is $g\pi(R^2 y - y^3/3)$ since the density of the water is

1 gm/cm³. The unbalanced, buoyant force acting on the sphere must be this extra weight of displaced water. Then, since the force is a restoring one, Newton's Second Law gives us

$$(1/2)(4/3) \pi R^3 \ddot{y} = -g\pi(R^2 y - y^3/3) \quad (3)$$

where the coefficient of y is the mass of the sphere. The same equation of motion follows if the motion begins with the center of the sphere lifted a distance q above the water level. The equation of motion can be simplified to become

$$2R^3 \ddot{y} = -g(3R^2 y - y^3).$$

Noting that $\ddot{y} = \dot{y}(d\dot{y}/dy)$ we can antidifferentiate to obtain

$$R^3 \dot{y}^2 = -g(3R^2 y^2/2 - y^4/4) + g(3R^2 q^2/2 - q^4/4) \quad (4)$$

since $y = q$ when $\dot{y} = 0$. This last equation is the analog of Equation 2 which we wrote for the bobbing block. After a bit of straightforward but tedious algebra, we can rewrite Equation 4 as

$$\left(2R \sqrt{\frac{R}{g(6R^2 - q^2)}}\right) \dot{y} = -q \sqrt{1 - \left(\frac{y}{q}\right)^2} \sqrt{1 - k^2 \left(\frac{y}{q}\right)^2}$$

where $k^2 = q^2/(6R^2 - q^2)$. The negative sign on the righthand side of the equation was chosen since we intend to look at the motion of the sphere only during the first quarter of its period while \dot{y} and y have opposite algebraic signs. Note that as $q \rightarrow 0$, $k \rightarrow 0$ also and we return to the simple harmonic approximation for the motion.

Letting $y/q = \sin s$ and $\dot{y} = dy/dt = q(\cos s)(ds/dt)$ and making the appropriate substitutions in the last equation, we can write

$$-dt = 2R \sqrt{\frac{R}{g(6R^2 - q^2)}} \cdot \frac{ds}{\sqrt{1 - k^2 \sin^2 s}} \quad (5)$$

If we now integrate both sides of Equation 5 over the first quarter period of motion ($T/4$), we obtain the desired integral formula for the period of oscillation

$$T = 8R \sqrt{\frac{R}{g(6R^2 - q^2)}} \cdot \int_0^{\pi/2} \frac{ds}{\sqrt{1 - k^2 \sin^2 s}}$$

where k is as previously defined. The definite integral is a complete elliptic integral of the first kind with modulus k . Such integrals have been studied extensively.

OBSERVATIONS

Certainly neither the mathematics nor the physical arguments which we have presented are new. In fact, they are so "old fashioned" that they are quite likely to be unfamiliar and hence interesting to students today. The derivation of the frequency for the bobbing block can serve as an assignment for beginning physics

students, and the derivation of the frequency for the sphere can serve as a project for more advanced students who have already thought about the simple pendulum swinging through large angular displacements. The problem for the sphere can be made more difficult by taking its specific gravity to be something other than 0.5. Then the equilibrium water level will not be at a horizontal equator of the sphere, and the bobbing of the sphere will no longer be symmetric with respect to the equator.

When divorced from our derivation, the evaluation of the definite integral for the period of our bobbing sphere furnishes a nice exercise in numerical integration and computer programming. Such an exercise motivated this note. We chose to give our derivation in the c.g.s. system of units because the unit density of water seemed to simplify our notation. However, once we have the formula before us, we can use any system we like provided that we give g , the acceleration due to gravity, in the appropriate units. For example, we used Simpson's Rule to find the period of oscillation for a sphere of radius one foot when q , the initial depth of the center, was taken to be the radius. We took g to have the value 32.174 ft/sec^2 . We ran our program on an Apple IIe computer and obtained a period of 1.107 sec.

In doing the mathematics for the bobbing sphere there is a great deal to be learned about integration. Just as Equations 1 and 2 can be solved in closed form with the circular functions, Equations 3 and 4 can be solved in closed form with the elliptic functions. Equation 4 is satisfied by Legendre's sine amplitude function

$$y = \text{sn} \left(\frac{\sqrt{g(6R^2 - q^2)}}{2R\sqrt{R}} t + \delta, k \right)$$

with domain taken to be the set of real numbers (Moulton). Although we still concede that the mathematics of our problem has been well understood for a long time, we suspect that it is not well known to students that every integral of the form

$$\int R(x, \sqrt{\sum_{i=0}^4 a_i x^i}) dx,$$

where R is a rational function, can be expressed in terms of the elementary functions and elliptic integrals (Sokolnikoff and Redheffer).

Because of its many ramifications and possible extensions, we feel that the problem of the bobbing sphere provides a useful and rewarding project for the physics or applied mathematics class.

A FINAL NOTE

This paper (as regarded by its author) is an exercise in well established but now unfamiliar mathematics and not a rigorous derivation of an equation of motion. In the "good old days of closed form solutions," a distinguishing mark of a fine mathematician was his ability to recognize (before attempting) problems which were solvable and to make (within reason) whatever simplifying assumptions were necessary to produce manageable, yet still reasonable models of physical processes.

That is, he had a feel for the "simplest, meaningful" problem. The simplifying assumption about the bobbing sphere which leads to an "elegant" closed form solution is that the total force by the liquid on the sphere is the buoyant force of Archimedes' Principle. In actuality, that force would be the total force only in the case of static equilibrium. However, if the displacements and velocities of the sphere are taken to be small, the substitution of the buoyant force for the total force seems not unreasonable and is in the spirit of the "simplest, meaningful" problem. In addition, we ought to note that the computation for the period when the sphere is initially submerged stretches the model to an extent that it may become suspect to the physicist while remaining pleasing to the mathematician.

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XPS Analysis of Reduced Iron Magnetically Extracted from Iron Fortified Breakfast Cereals

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ABSTRACT

Reduced iron powder was magnetically extracted from commercially available iron fortified breakfast cereals. X-ray photoelectron spectroscopy (XPS) studies determined that the outermost 5 nm of the extracted iron contained primarily carbon and oxygen with a small amount of iron and nitrogen. Argon and oxygen plasmas were used to remove the outer layer of organic contamination from the iron and increase the percentage of iron in the surface. The iron binding energy indicated that the outermost layer of the extracted iron was oxidized. The size of the iron particles was approximated from scanning electron microscope (SEM) photomicrographs.

INTRODUCTION

Cereal products are commonly enriched with iron to decrease the prevalence of anemia in the population (Baynes and Bothwell, 1990 and Fritz et al., 1975) and to replace naturally occurring iron that is lost during processing. Milling removes up to seventy-five percent of the iron phytate naturally occurring in wheat (Schroeder, 1971 and Ranum and Loewe, 1978). Iron enrichment of bread is mandatory in thirty-six states and in one territory, but fortification of breakfast cereal is voluntary (Reference Source, 1989).

Bioavailability is a measure of the ability of iron to be ingested by the body and varies with the chemical form of the iron, iron particle size, interaction of the iron with other diet components, chelation, and the body's need for iron (Ranum and Loewe, 1978). Standards for iron fortification are based upon iron quantity without accounting for differences in nutritional quality or bioavailability between iron sources (Davidson and Russo, 1976). Choice of a chemical form of iron for enrichment of a breakfast cereal requires a compromise between bioavailability, compatibility with the finished product, processing limitations and cost (Harrison et al., 1976). For example, ferrous sulfate has very high bioavailability but it may discolor or catalyze rancidity in breakfast cereals (Ranum and Loewe, 1978 and Davidson and Russo, 1976).

The most common source of iron used to enrich breakfast cereals is reduced iron powder (Ranum and Loewe, 1978 and Davidson and Russo, 1976). Reduced iron powder is dark metallic gray, insoluble in water, magnetic (Ranum and Loewe, 1978 and Davidson and Russo, 1976) and "generally recognized as safe" by the Food and Drug Administration for use as a dietary supplement (Code of Fed. Reg. part

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182.5375, 1990). Reduced iron powders of very small particle size are manufactured commercially by four different methods: high temperature reduction of ground iron oxides by hydrogen or carbon monoxide, electrolytic reduction of ferric iron to "electrolytic iron", and reaction of iron and carbon monoxide to form iron pentacarbonyl which is decomposed to give "carbonyl iron" and carbon monoxide (Ranum and Loewe, 1978). The ability of reduced iron particles to dissolve in the digestive system and be absorbed by the body is effected by the method of manufacture, particle size, solubility in dilute HCl, chemical impurities, surface area, porosity, and age (Ranum and Loewe, 1978). Oxidation of the iron surface or "rusting" decreases the availability of the iron to the body (Fritz et al., 1975 and Ranum and Loewe, 1978). Table 1 compares the relative bioavailability of several chemical forms of iron (Fritz et al., 1975).

Teflon[®]*-coated magnetic stir bars are used in the literature to recover reduced iron, added by researchers, from food suspended in water (Kadan and Ziegler, 1987 and Lee and Clydesdale, 1979) and from cereal in milk (Clydesdale and Nadeau, 1984). Kadan and Zeigler added reduced iron particles to powdered cereal mixes, processed the dry mix into breakfast flakes, recovered the iron magnetically, and used x-ray photoelectron spectroscopy (XPS) to determine the iron binding energy and to conclude that the iron surface was oxidized (Kadan and Ziegler, 1987). XPS provides the elemental composition of approximately the outermost 5 nm of a sample surface. X-rays of a characteristic energy irradiate the sample causing photoelectrons to be ejected and detected. The binding energy of an ejected electron is characteristic of the element to which the electron was bound. Small changes in the binding energy of an element, known as "chemical shifts", are due to differences in chemical bonding between atoms (Filbey and Wightman, 1991).

In this study, the reduced iron was extracted from breakfast cereals that are commercially available, rather than processed in the laboratory. The elemental composition of the outermost 5 nm of the iron particle surface and the chemical bonding between the surface atoms was characterized using XPS. Oxygen and argon plasma treatments were used to remove a layer of carbon and oxygen, determined to be carbohydrate cereal residue, from the iron surface. The size and shape of the iron particles was examined using the scanning electron microscope (SEM).

EXPERIMENTAL

The breakfast cereals in this study were Whole Wheat Total^{®**}, Total Cornflakes, and Kellogg's Cornflakes purchased from a local grocery store. Total Cornflakes and Whole Wheat Total both contain 100% of the U.S. Recommended Daily Allowance (RDA) for iron per 28.4 grams (or 1 serving) and Kellogg's Cornflakes contains 10%***. The RDA of iron is 18 milligrams for adults and children four or more years of age (Code of Fed. Regs. part 104.47, 1990).

* Teflon is a registered trademark of E. I. du Pont de Nemours & Co., Inc.

** Total is a registered trademark of General Mills, Inc.

*** Percentages obtained from nutrition information on breakfast cereal box.

TABLE 1. Bioavailability of Iron from Selected Sources (Fritz et al., 1975).

Iron Form	Particle Size	Relative Biological Value
Ferrous sulfate	---	100
Reduced iron		
H ₂ reduction	10 - 20 microns	54
	325 mesh	34
	100 mesh	18
CO reduction	7 - 10 microns	36
	14 - 19 microns	21
	27 - 40 microns	13
Carbonyl iron	4 microns	69
	3 - 5 microns	69
	4 - 8 microns	64
Electrolytic iron	0 - 10 microns	76
	10 - 20 microns	75
	20 - 40 microns	48
	> 40 microns	45
Ferric oxide (Rust)	---	4

Magnetic Extraction *

The breakfast cereal was crushed manually. Two clean 400 mL beakers and a clean 3.8 cm long Teflon-coated magnetic stir bar were rinsed with distilled, deionized H₂O (DD H₂O). One beaker was filled with DD H₂O and set aside. The magnetic stir bar was placed in the second beaker and enough crushed cereal was added to fill the beaker approximately two-thirds full. DD H₂O was added to fill the beaker. The cereal was allowed to absorb water and DD H₂O was added to refill the beaker. The cereal slurry was stirred magnetically for 20 to 30 minutes. The magnetic stir bar was carefully removed from the cereal slurry with non-metallic forceps and placed in the reserved beaker full of DD H₂O. The stir bar holding the extracted iron was magnetically stirred in the DD H₂O for several minutes to remove all visible cereal residue from the iron. The stir bar was removed with non-metallic forceps, placed on a clean watch glass, and dried in a 100°C oven for 10 to 15 minutes. A beaker of DD H₂O was magnetically stirred for 30 minutes as a control.

Once the iron was extracted from the cereal an effort was made to minimize exposure time of the iron to the atmosphere by proceeding immediately from extraction to plasma treatment to XPS analysis with minimal time delay. To

* Secondary school teachers should note that this experimental protocol lends itself to classroom demonstrations and science fair projects.

investigate the effect of the atmosphere, a sample of iron extracted from Total cornflakes was exposed to ambient conditions for two weeks prior to XPS analysis.

Plasma Treatment

The extracted iron was transferred from the magnetic stir bar to a small piece of ferro-type plate for plasma treatment. A Tegal Plasmod[®] was used to produce a radiofrequency (13.56 MHz)-generated 50 W plasma of argon or oxygen. The iron particles were treated in an argon plasma for various periods of time between 5 and 40 minutes or with an oxygen plasma for 5 minutes. The plasma treated iron powder was immediately secured on an XPS sample mount with double-sided transparent tape.

X-Ray Photoelectron Spectroscopy (XPS)

XPS analysis was performed with a Perkin-Elmer PHI 5300 spectrometer employing a Mg K α (1253.6 eV) achromatic x-ray source operated at 15 keV with a power of 400 watts and a take-off angle of 90°. Survey scans were taken in the range of 0-1000 eV and narrow scans were obtained on any significant peaks observed in the survey scan spectra. The binding energy of each photopeak was referenced to C1s at 285.0 eV. The Perkin-Elmer 7500 computer (PHI software version 2.0) was used to obtain peak areas and for curve-fitting. The C1s region was curve-fitted with a full width at half maximum (FWHM) of 1.7 ± 0.1 eV and the O1s with FWHM of 2.0 ± 0.1 eV.

The iron powder magnetically extracted from the breakfast cereal was analyzed with XPS as removed from the cereal, after argon and oxygen plasma treatments, and after exposure to ambient conditions for 2 weeks. Manually crushed Whole Wheat Total cereal was also examined with XPS.

Scanning Electron Microscopy (SEM)

The extracted iron powder was secured on an SEM mount with double-sided transparent tape and sputter-coated with gold using an Edwards Sputter Coater S150B. An ISI-SX-40 SEM was used to obtain photomicrographs at 250X magnification. The iron particle size was approximated from three photomicrographs for each cereal.

RESULTS AND DISCUSSION

The magnetic iron particles extracted from the cereal clung together on the ends of the stir bar in strands. The very fine dark gray powder was insoluble in H₂O and dissolved in 3N HCl over a twenty-four hour period. Visual inspection showed no iron powder present on the control stir bar, a very small amount of iron for Kellogg's Cornflakes and a much greater amount for the two Total cereals. Approximately equal amounts of iron were removed from Whole Wheat Total and Total Cornflakes. These observations were anticipated as Total Cornflakes and Whole Wheat Total are fortified with 18 mg of iron per 28.4 grams (or 1 serving) and Kellogg's Cornflakes is fortified with only 1.8 mg of iron per 28.4 grams.

The XPS calculated atomic percentages are presented in Table 2 for each element in the surface of the magnetically extracted iron powder. These results show that the outermost 5 nm of the iron as extracted from the breakfast cereal contains primarily carbon and oxygen and less than 5% iron and nitrogen. The

TABLE 2. Elemental Composition of the Outermost 5 nm of the Reduced Iron Magnetically Extracted from Breakfast Cereal.

Carrier Cereal	Plasma Treatment	Atomic Concentration (%)			
		C1s	O1s	Fe2p	N1s
Whole Wheat	No plasma*	70	25	3	2**
Total	Ar - 5 min.	83	17	0	---
	Ar - 40 min.	63	28	6	3
	O ₂ - 5 min.	34	50	16	0
Total	No plasma	78	20	1	1
Cornflakes	No plasma				
	(2 wks. air exposure)	60	35	4	1
	Ar - 20 min.	84	13	1	2
	Ar - 40 min.	66	26	5	3
	O ₂ - 5 min.	48	39	12	1
Kellogg's Cornflakes	No plasma	73	23	2	2
	Ar - 30 min.	81	15	1	3
	O ₂ - 5 min.	51	38	10	1

* Iron as extracted from the breakfast cereal

** N1s region not scanned

intensities of the Fe2p photopeaks of the iron powders, as extracted from the breakfast cereals, were low due to the small percentage of iron in the surfaces. The iron valence state could not be positively determined. Plasma treatment was used to remove an outer layer of organic contamination and expose more iron for characterization.

Argon plasma, even up to 40 minutes, followed by exposure to the atmosphere was relatively ineffective in cleaning the iron surface. There is evidence in the literature that an argon plasma generates stable free radicals in the sample surface which react with room air upon exposure. Carbon and oxygen redeposit on the surface because there is no mechanism for converting the molecular fragments removed from the surface into permanently volatile compounds (Liston, 1989). A purge of hydrogen following plasma treatment might greatly increase the cleaning effectiveness of the argon plasma, but was not attempted. Oxygen plasma treatment for only 5 minutes removed the organic contamination and resulted in a 500% or greater increase in the concentration of surface iron as given in Table 2. An oxygen plasma is capable of oxidizing the carbon and oxygen fragments ablated from the sample surface into volatile species such as CO, CO₂ and H₂O (Liston, 1989). The effect of the argon and oxygen plasma treatments on the Fe2p photopeaks of the reduced iron magnetically extracted from Whole Wheat Total, Total Cornflakes, and Kellogg's Cornflakes are shown in Figures 1, 2, and 3, respectively.

The C1s and O1s regions are shown in Figures 4, 5 and 6 and the respective curve-fitting results are tabulated in Tables 3 and 4. The most intense C1s photopeak was positioned at 285.0 eV and is assigned to CH_x. Three higher binding

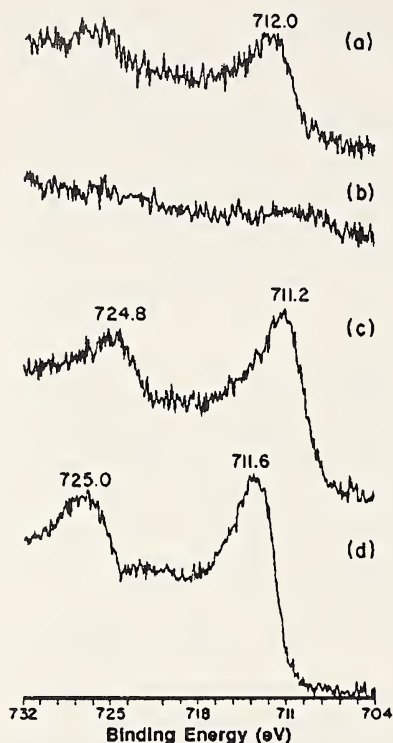


FIGURE 1. XPS Fe2p Region of Reduced Iron Magnetically Extracted from Whole Wheat Total Breakfast Cereal. (a) No plasma treatment. (b) 5 min. Ar plasma treatment. (c) 40 min. Ar plasma treatment. (d) 5 min. O₂ plasma treatment.

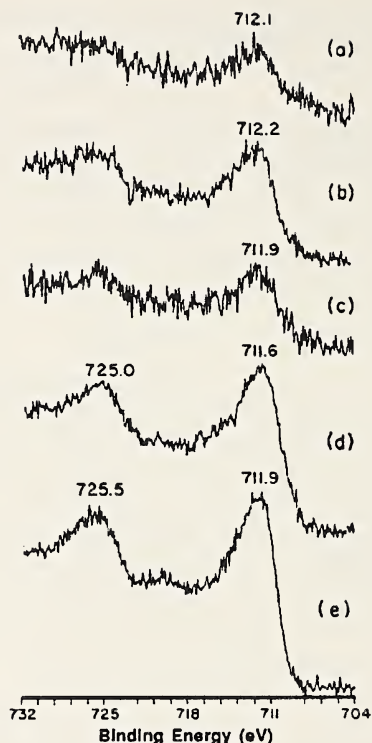


FIGURE 2. XPS Fe2p Region of Reduced Iron Magnetically Extracted from Total Cornflakes Breakfast Cereal. (a) No plasma treatment. (b) 2 weeks air exposure and no plasma treatment. (c) 20 min. Ar plasma treatment. (d) 40 min. Ar plasma treatment. (e) 5 min. O₂ plasma treatment.

energy photopeaks were present and represent different carbon and oxygen environments. The photopeaks at approximately 286.6 eV, 287.9 eV and 289.0 eV are assigned to C-O, O-C-O and/or C=O, and O-C=O bonding, respectively (Clark et al., 1978). When the iron extracted from Whole Wheat Total was treated in an argon plasma for 5 minutes, a peak appeared at 283.7 eV and could not be positively identified. The O1s region contained a C-O photopeak at approximately 533.7 eV, a C=O photopeak around 532.8 eV and an iron oxide photopeak at approximately 530.7 eV (Clark et al., 1978). The intensity of the O1s iron oxide peaks increased as the intensity of the Fe2p photopeaks increased. The C1s and O1s regions of the crushed Whole Wheat Total cereal shown in Figure 7 correlate well with the carbon and oxygen on the iron surface shown in Fig. 4a and suggest that the iron powder extracted from the whole wheat Total was coated with a layer of carbohydrate cereal residue.

The iron extracted from Total Cornflakes and exposed to room air for two weeks became faintly dark orange in color and XPS analysis showed an increase in the amount of iron in the surface relative to the amounts of carbon and oxygen. The percentage of iron in the surface increased as the outer layers "rusted" or corroded

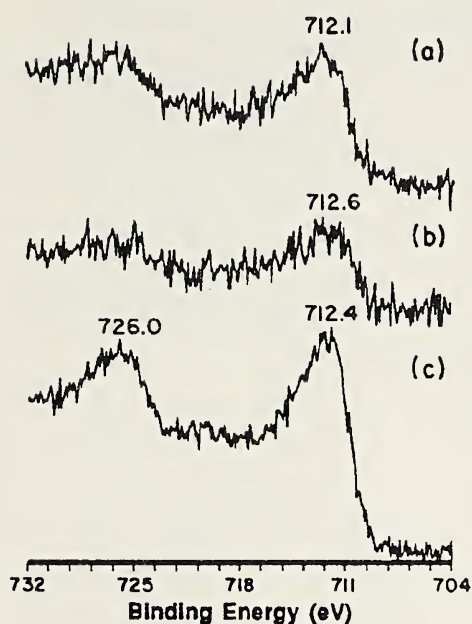


FIGURE 3. XPS Fe2p Region of Reduced Iron Magnetically Extracted from Kellogg's Cornflakes Breakfast Cereal. (a) No plasma treatment. (b) 30 min. Ar plasma treatment. (c) 5 min. O₂ plasma treatment.

TABLE 3. C1s Curve-fitting Results for Reduced Iron Magnetically Extracted from Breakfast Cereals.

Carrier Cereal	Fig.	Plasma Treatment	Atomic Concentration (%)				
			Binding Energy (eV)				
			289.0	287.9	286.6	285.0	283.7
Whole Wheat Total	4a	No plasma*	6	5	20	69	--
	4b	Ar - 5 min.	5	3	12	65	15
	4c	Ar - 40 min.	7	4	17	72	--
	4d	O ₂ - 5 min.	11	6	20	63	--
Total Cornflakes	5a	No plasma	5	3	19	73	--
	5b	No plasma (2 wks air exposure)	4	7	33	55	--
	5c	Ar - 20 min.	8	--	18	74	--
	5d	Ar - 40 min.	7	1	14	77	--
	5e	O ₂ - 5 min.	9	2	20	50	--
Kellogg's Cornflakes	6a	No plasma	9	2	20	69	--
	6b	Ar - 30 min.	8	--	18	75	--
	6c	O ₂ - 5 min.	7	4	21	69	--

* Iron extracted from the breakfast cereal

TABLE 4. O1s Curve-fitting Results for Iron Magnetically Extracted from Breakfast Cereals.

Carrier Cereal	Fig.	Plasma Treatment	Atomic Concentration (%)				
			535.5	Binding Energy (eV)			
				533.7	532.8	530.7	528.7
Whole Wheat	4a	No plasma*	2	42	36	19	--
Total	4b	Ar - 5 min.	--	31	46	20	4
	4c	Ar - 40 min.	--	27	45	28	--
	4d	O ₂ - 5 min.	--	16	40	44	--
Total	5a	No plasma	3	49	36	12	--
Cornflakes	5b	No plasma (2 wks. air exposure)	--	57	22	21	--
	5c	Ar - 20 min.	--	42	50	8	--
	5d	Ar - 40 min.	--	19	51	30	--
	5e	O ₂ - 5 min.	--	17	32	51	--
Kellogg's	6a	No plasma	--	27	57	15	--
Cornflakes	6b	Ar - 30 min.	--	45	48	7	--
	6c	O ₂ - 5 min.	--	15	40	44	--

* Iron as extracted from the breakfast cereal

TABLE 5. Fe2p Region Characteristic Binding Energies.

Sample Description		Fe2p3/2 Binding Energy (eV)	Fe2p1/2 and Fe2p3/2 Separation (eV)
Fe ⁰		710.0 ^a	13.2 ^b
Fe ₂ O ₃		712.6 ^a	13.6 ^b
Reduced iron magnetically extracted from:			
Whole Wheat	No plasma treatment	712.0	---
Total	Ar plasma - 5 min.	---	---
	Ar plasma - 40 min.	711.2	13.6
	O ₂ plasma - 5 min.	711.6	13.4
Total	No plasma treatment	712.1	---
Cornflakes	No plasma treatment (2 wks. air exp)	712.2	---
	Ar plasma - 20 min.	711.9	---
	Ar plasma - 40 min.	711.6	13.4
	O ₂ plasma - 5 min.	711.9	13.6
Kellogg's	No plasma treatment	712.1	---
Cornflakes	Ar plasma - 30 min.	712.6	---
	O ₂ plasma - 5 min.	712.4	13.6

a. Kadan and Ziegler, 1987

b. Waghorn, 1979

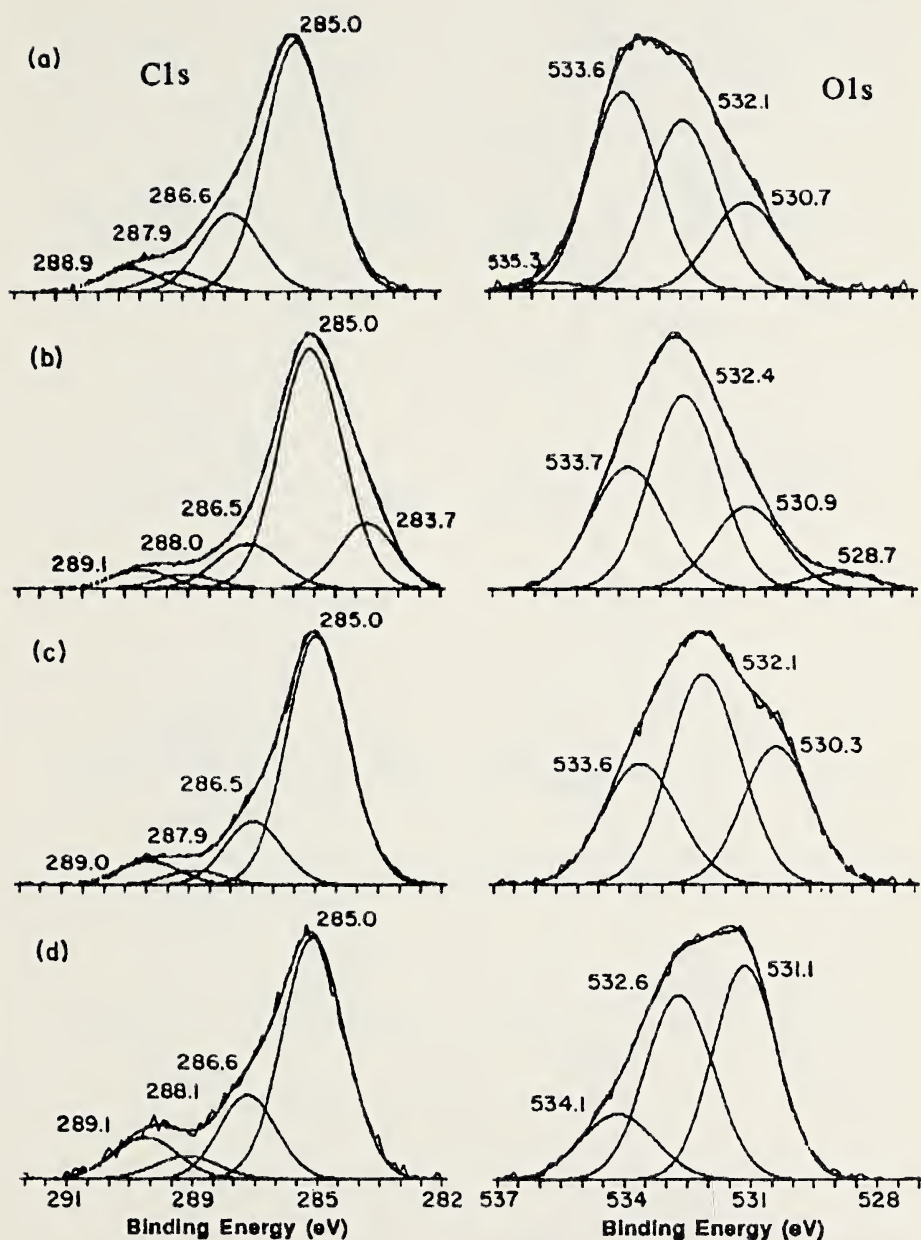


FIGURE 4. Curve-fit C1s and O1s Regions of Reduced Iron Magnetically Extracted from Whole Wheat Total Breakfast Cereal. (a) No plasma treatment. (b) 5 min. Ar plasma treatment. (c) 40 min. Ar plasma treatment. (d) 5 min. O₂ plasma treatment.

increasing the total surface area of the particle by "pitting" and exposing iron that lay just below the surface. Table 5 compares the binding energies of reduced iron and ferric oxide found in the literature (Kadan and Ziegler, 1987 and Waghorn, 1979) to all well resolved Fe2p photopeaks. Both the binding energies of the

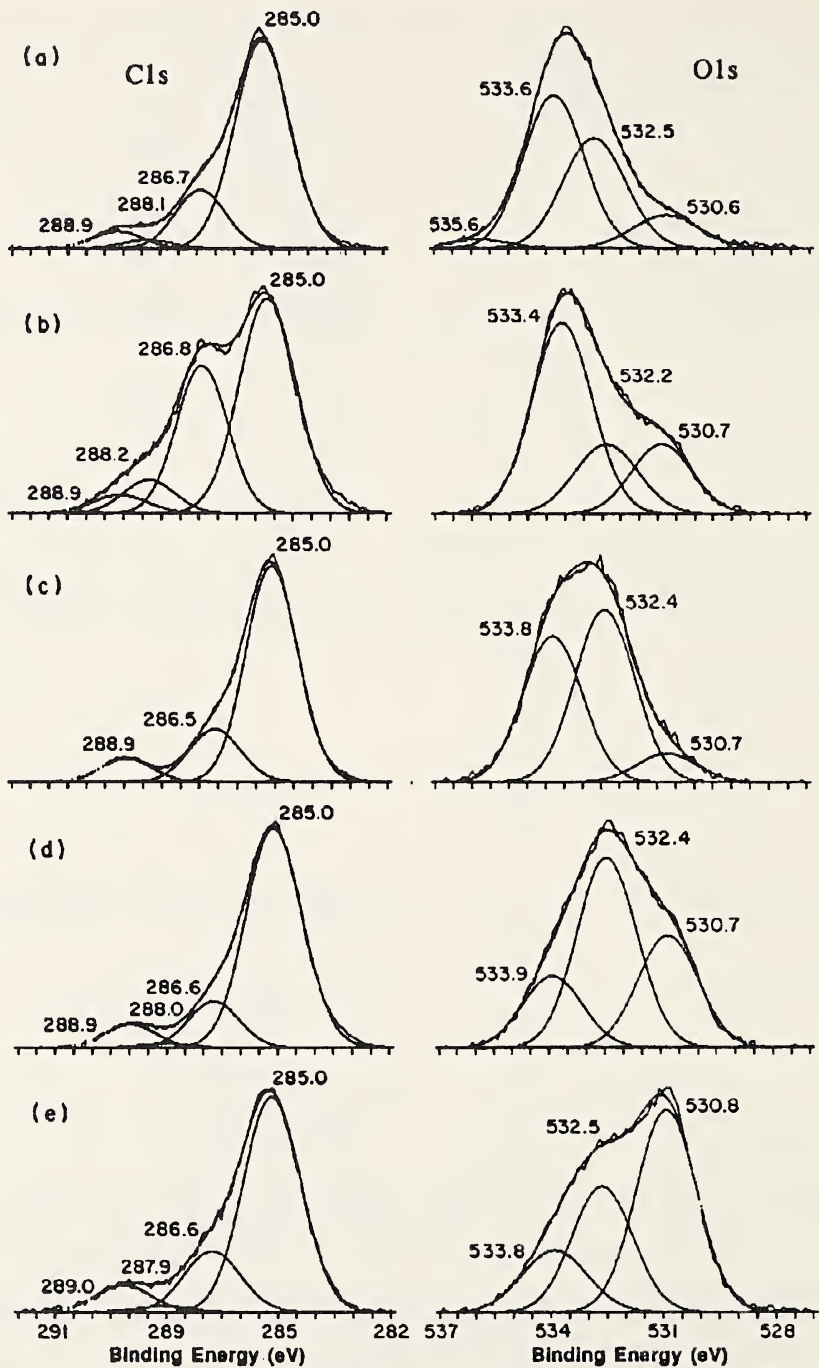


FIGURE 5. Curve-fit C1s and O1s Regions of Reduced Iron Magnetically Extracted from Total Cornflakes Breakfast Cereal. (a) No plasma treatment. (b) 2 weeks air exposure and no plasma treatment. (c) 20 min. Ar plasma treatment. (d) 40 min. Ar plasma treatment. (e) 5 min. O2 plasma treatment.

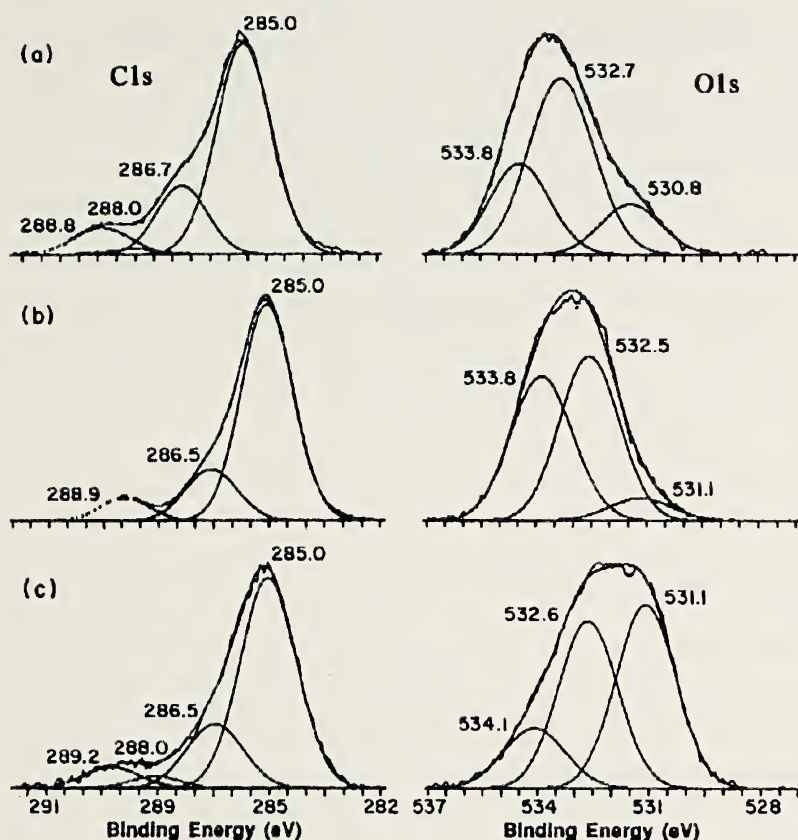


FIGURE 6. Curve-fit C1s and O1s Regions of Reduced Iron Magnetically Extracted from Kellogg's Cornflakes Breakfast Cereal. (a) No plasma treatment. (b) 30 min. Ar plasma treatment. (c) 5 min O2 plasma treatment.

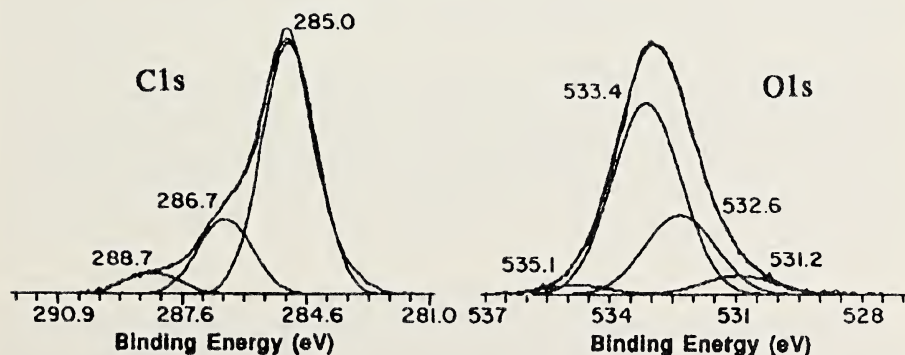


FIGURE 7. Curve-fit C1s and O1s Regions of Crushed Whole Wheat Total Breakfast Cereal.

Fe2p_{3/2} photopeaks and the separation between the Fe2p_{3/2} and Fe2p_{1/2} photopeaks of the iron powder as extracted from the cereal, after exposure to the atmosphere for two weeks, and after argon or oxygen plasma treatment are closer to the literature values for ferric oxide than for reduced iron. Therefore, the XPS analysis showed that the outer molecular layers of the reduced iron, as extracted from the breakfast cereal, were oxidized. However, because the Fe2p binding energies were slightly less than the literature values for ferric oxide (Fe₂O₃), iron oxides in both the Fe²⁺ and the Fe³⁺ valence states might be present on the iron surface. The Fe2p_{3/2} binding energy of ferrous oxide (FeO), in the Fe²⁺ valence state, would be shifted above that of reduced iron, but would not be as high as the Fe2p_{3/2} binding energy of ferric oxide, in the Fe³⁺ valence state (Waghorn, 1979). The presence of a combination of iron oxides, in both the Fe²⁺ and Fe³⁺ valence states, would account for the Fe2p_{3/2} binding energies of the extracted iron particles listed in Table 5, but was not confirmed.

There is no way to conclude from this study whether or not the iron surface was oxidized while in the cereal or if it became oxidized during the magnetic extraction and drying procedure. It has been shown in the literature that the surface of reduced iron is oxidized even before it is added to foods (Kadan and Ziegler, 1987). The extreme oxidizing effect of the oxygen plasma treatment did not change the binding energy of the Fe2p photopeaks which supports the proposal that the iron was oxidized before it was plasma treated. Reduced iron and ferric ferrous oxide (Fe₃O₄) are magnetic, but Fe₂O₃ and FeO are not magnetic. All extracted iron samples remained magnetic after extraction, plasma treatment, and XPS analysis. Therefore, only the outermost molecular layers of the extracted iron powder contained Fe₂O₃ and FeO, but the interior was magnetic iron.

SEM photomicrographs of the extracted iron magnified 250X revealed that the particles were rough and irregular in shape, resembling pieces of gravel. The iron particles ranged from approximately 8 to 80 microns in diameter.

SUMMARY

The relative amount of reduced iron powder magnetically extracted from three iron fortified breakfast cereals, Whole Wheat Total, Total Cornflakes and Kellogg's Cornflakes, corresponded to the level of iron enrichment as calculated from the % U.S. RDA supplied by the cereal. The extracted iron particles were coated with carbohydrate cereal residue which was most effectively removed with a 5 min. oxygen plasma treatment. XPS studies showed that the surface of the reduced iron powder as extracted from the breakfast cereal was oxidized. Plasma treatment and exposure of the iron particles to the atmosphere increased the percentage of iron in the surface, but did not effect the binding energy of the Fe2p photopeaks corresponding to oxidized iron.

ACKNOWLEDGEMENT

The help of Frank Cromer with the XPS and SEM work is appreciated. Ms. Heisey performed all experimental work and prepared this manuscript. Dr. Burch contributed the magnetic extraction procedure. Dr. Wightman provided technical assistance with the experiments and with this paper.

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Observations of the Phytoplankton Standing Crop at the Shelf Margin of the Mid Atlantic Bight

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ABSTRACT

A comparison of the total percentage cell abundance and cell biovolume relationships of major phytoplankton categories was made between two station sets across the shelf margin. Diatom values for abundance and biovolume were greater at oceanic stations compared to the outer shelf stations, with dinoflagellates having the reverse pattern. The composite contributions to biovolume and abundance in the standing crop from other phytoplankton categories were greater over the outer shelf than beyond the shelf margin. The major source of biovolume (biomass) from the outer shelf and these oceanic stations came from the diatoms and dinoflagellates, with an average mean of 93% of the total phytoplankton standing crop.

INTRODUCTION

Long term seasonal phytoplankton patterns of the United States northeastern shelf waters have been discussed by Marshall (1978, 1984a, 1984b). These papers characterize the seasonally dominant species of the near surface waters and support the chlorophyll abundance and productivity distribution values for this region as given by O'Reilly and Boush (1984). Cell abundance and productivity decrease from the near coastal waters seaward over the shelf, then increase along the shelf margin (Marshall, 1984a, O'Reilly and Boush, 1984). This region is influenced by current patterns parallel to and over the shelf, with warm core rings also moving southward along this slope. Walsh et al. (1976) noted the total biomass of diatoms increased with depth into oceanic waters while dinoflagellates remained fairly constant, decreasing slightly with depth. Glover et al. (1985) found the ultraplankton accounted for 65 to 97% of the total phytoplankton in this region, with the cyanobacteria most numerous at the surface and the eucaryotes dominant at the lower light levels. Beers et al. (1975) noted phytoplankton concentrations fairly constant to 100 m, then decreasing to 200 m, with biomass maxima in the upper 20 m. In the mid-atlantic bight, Cosper and Stepien (1984) found diatoms and dinoflagellates accounted for the majority of the phytoplankton biomass in waters over the shelf, shelf break and slope. Colton et al. (1985) reported the piconoplankton fraction represented 71% of the total cell counts for all depths, averaging 34.9×10^4 cells/l. Diatoms were the next most abundant group, representing 16% (8.0×10^4 cells/l) of the total.

The objectives of this paper are to present data on the spatial relationships of phytoplankton at sites across the shelf margin, that will include comments on their abundance and biovolume along a north-south gradient and over a vertical range of depths at these locations.

METHODS

Water samples were taken in April 1984 aboard the R/V CAPE HENLOPEN at stations near the outer northeastern shelf margin of the United States (Figure 1). Stations D-46 and C-47 were oceanic sites beyond the shelf break located approximately 130 km apart, with stations D-35 and C-36 along the inner shelf margin in waters of less than 150 m deep. Phytoplankton from these two oceanic and two shallow shelf stations will be discussed in this report.

At each station a series of water samples were taken with Go- Flo bottles at mean depth values of 1.0, 27.3, 78.1 and 141.6 m. From each depth sampled, three 500 ml water samples were taken and preserved with buffered formalin and returned to the laboratory for analysis. These samples were examined using a modified Utermohl method, where cell counts were made for phytoplankton components to obtain an 85% abundance accuracy estimate (Venrick, 1978; Marshall, 1984a). The autotrophic picoplankton counted were limited to cells of approximately 1.5 to 2.0 microns in size. At each sampling depth, samples were taken in triplicate, with mean concentrations recorded for each taxon. Cell volume data were previously determined by Marshall (1984a).

RESULTS

A total of 168 taxa were identified at these stations and consisted mainly of diatoms (78) and dinoflagellates (52) (Wagoner, 1988). A variety of phytoflagellates and a ubiquitous cyanobacteria component were also present, with several unidentified cells of 1.5 to 10 microns in size placed in several pico-nanoplankton categories. These groups consisted of mainly cyanobacteria cells less than 2 microns in size (picoplankton). Vertical abundance and cell volume (biomass) comparisons of the four stations are given in Figure 2. There is a general pattern of reduced cell concentrations in the upper strata southward, with highest concentrations (16×10^5 cells/l) at the more northern stations both over the shelf and seaward. Abundance levels continued to decrease with depth, with more similar values at each site below 27 m. Each of these stations was characterized by surface populations dominated by phytoflagellates, cyanobacteria, chlorophytes and the pico-nanoplankton categories. The highest concentrations of diatoms, chrysophytes and coccolithophores were above 27 m, before each of these groups decreased in abundance with greater depth. The increased presence of the diatoms at this sub-surface depth was responsible for the peak biovolume values noted there at several of the stations (Figure 2). Over the vertical range sampled at both shelf and oceanic stations, the major source of phytoplankton biovolume (biomass) in the standing crop came from the dinoflagellates and diatoms. The percentage attributed to dinoflagellates biovolume was greater over the shelf compared to the diatoms for the upper 78 m, below which the dinoflagellates amounts decreased and the diatoms percentage increased. At the oceanic stations, diatoms were the source of the greatest biovolume. This pattern continued to 140 m at the more northern station (D-46), whereas, the dinoflagellate contribution to the biovolume exceeded the diatoms below 78 m. The percentage abundance for the major components in the standing crop presents the expected dominance of the much smaller picoplankton (Figure 3). These values would also be much greater if the complete range (0.2- 2.0 microns) of the autotrophic picoplankton community had been

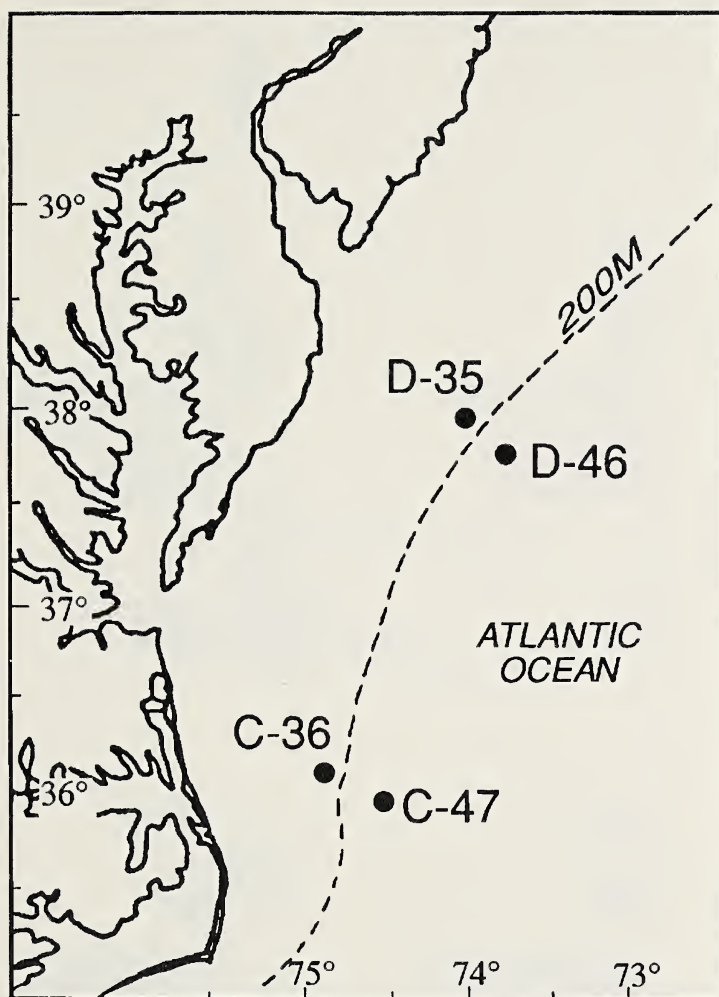


FIGURE 1. Station locations along the 200 meter depth contour of the continental shelf margin.

included and analysis not limited to light microscopy. The autotrophic picoplankters have been reported as ubiquitous in world oceans with concentrations in the North Atlantic at 10^6 - 10^7 cells/l (Murphy and Haugen, 1985). However, due to their small size their contribution to the volume of the standing crop is not great.

In general, the diatoms had their highest percentage contribution in the northern oceanic region compared to the other sites. There was also a greater contribution of a more diverse floral base over the shelf in comparison to the oceanic sites. The major contributors to the cell biovolume (biomass) of the standing crop of phytoplankton at these outer shelf and oceanic stations were diatoms and dinoflagellates (Figure 4). The dinoflagellate biovolume values decreased seaward, but increased southward, with the diatom proportion greater at the

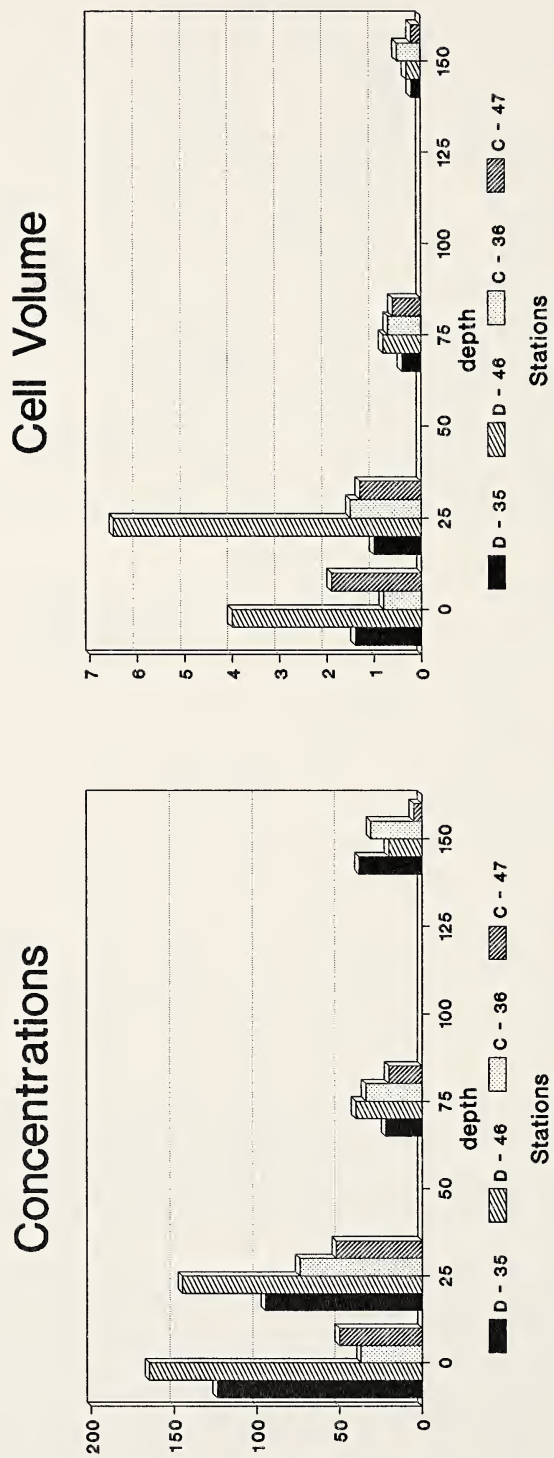


FIGURE 2. Vertical phytoplankton cell concentrations and cell volumes for stations along the continental shelf margin.

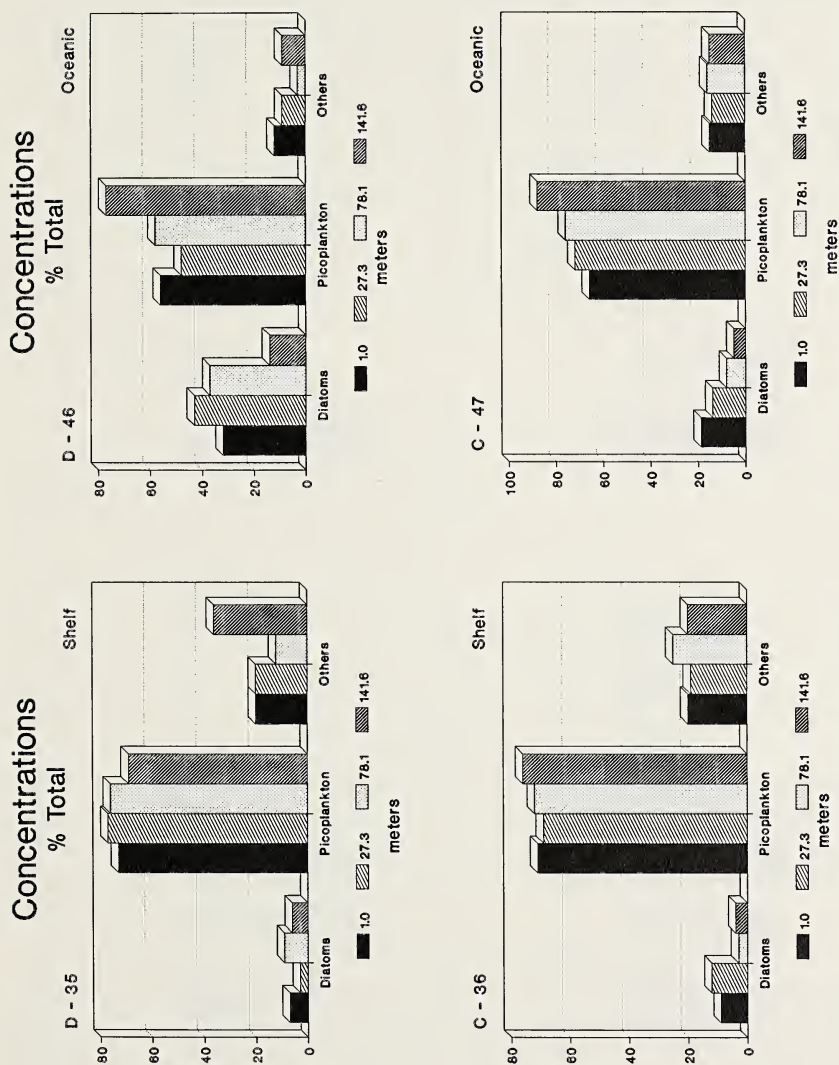


FIGURE 3. Phytoplankton concentrations, in percentage of the total abundance, attributed to diatoms, picoplankters and other categories for stations at mean depths sampled along the continental shelf margin.

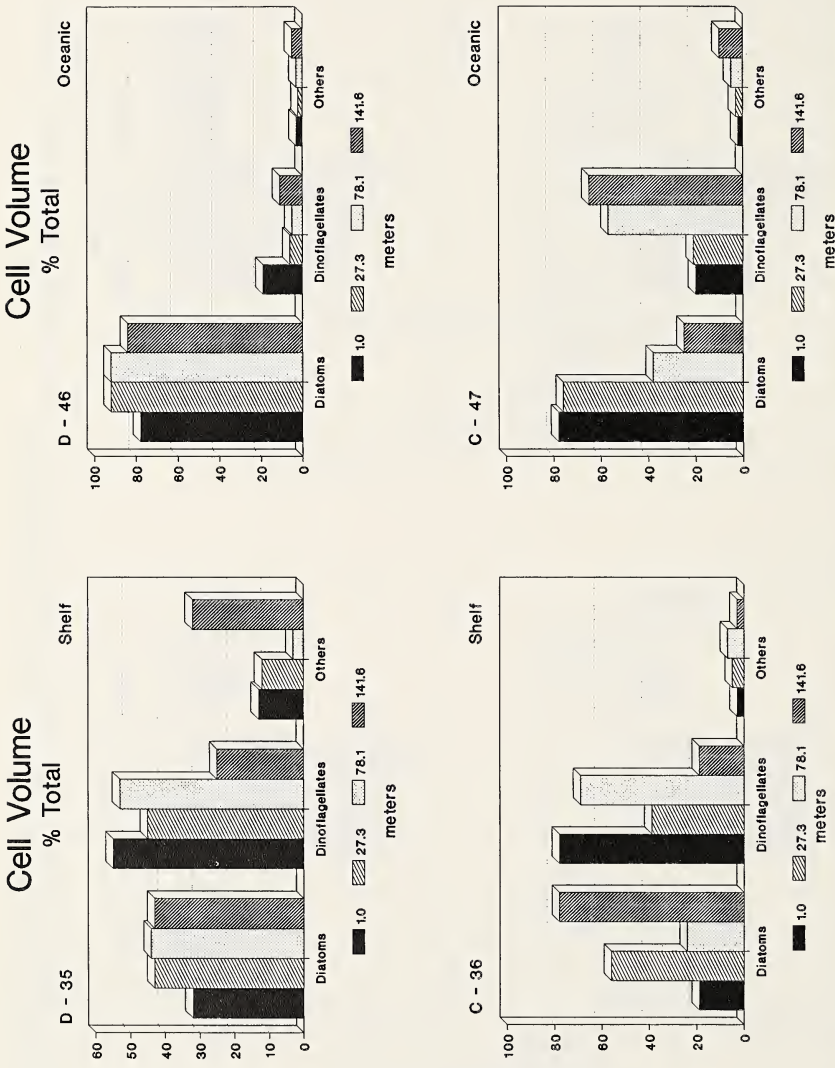


FIGURE 4. Phytoplankton cell volumes, in percentage of the total composition, for diatoms, dinoflagellates and other categories at mean depths sampled along the continental shelf margin.

northern stations over the different depths sampled. The other components were slightly more represented at the outer shelf stations, but decreased southward over the shelf and seaward. The cryptomonads and euglenoids had sporadic appearances where their concentrations were high and the contributions to the total biovolume increased. The combined mean contribution, over the vertical series, for the diatoms and dinoflagellates to the phytoplankton biovolume for these stations were: Shelf stations D-35 (85%), C-36 (95%); Oceanic stations D-46 (97%), C-47 (95%), with an overall mean of 93%.

Wagoner (1988) has also reported in further analysis of this data set, that the following patterns were found: 1. the dinoflagellates, cryptophyceans, and prasinophyceans decreased in abundance with depth; 2. the coccolithophores, diatoms and chrysophytes concentrations generally increased to 30 m, then decreased with depth over the next 150 m, 3. the chlorophytes and silicoflagellates had a mixed pattern above 30 m at all sites, but decreased in numbers below this depth, 4. the euglenoids were most abundant above 30 m over the shelf, and 5. the pico and nanoplankton abundance varied, but was most abundant at the surface, then decreased in numbers to 80 m where there was a similar continuation of reduced cell abundance.

CONCLUSIONS

The standing crop relationships for the major phytoplankton categories indicated several differences between stations over the outer shelf and seaward. Abundance and biovolume values were greater in the upper water strata, having greater abundance and biovolume associated with waters at the more northern stations, yet, being more comparable to each other at the lower depths. The proportional contribution of diatom numbers to the total increased seaward, as the other components generally decreased, with this pattern more developed at the northern stations. However, the biovolume from the diatoms and dinoflagellates was greater than all other constituents over the outer shelf and at the more seaward stations, with the dinoflagellates dominating the surface waters over the shelf. Diatoms and dinoflagellates together averaged 93% of the total phytoplankton biovolume (biomass) at these stations. The contributions from the mixed category of other phytoplankters was greatest over the northern shelf station (D-35), but decreased seaward and to the south. In contrast, the major contributor to the standing crop biovolume beyond the shelf were the diatoms, with the dinoflagellates the next most abundant source.

ACKNOWLEDGEMENTS

This study was conducted by Bruce Wagoner as part of a broader investigation of phytoplankton composition in the continental shelf waters of northeastern United States by Harold G. Marshall, and represents a portion of his masters thesis.

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A High Elevation Record for the Least Shrew, *Cryptotis parva* (Say)

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ABSTRACT

A least shrew (*Cryptotis parva*) was captured at 1524 m on Whitetop Mountain in Grayson County, Virginia. The locality is the highest for the species in Virginia by more than 575 m, and the highest for all of the United States. The habitat is basically a red spruce (*Picea rubens*) forest with scattered northern hardwood species.

A least shrew (*Cryptotis parva*) was captured at 1524 m (5000 ft) on Whitetop Mountain in Grayson county, Virginia, as part of a study to determine small mammal associates of the endangered northern flying squirrel (*Glaucomys sabrinus*). The record is the highest elevation reported for Virginia as well as most of North America. *C. parva* is known from as high as 2713 m (8900 ft) in Mexico (Choate, 1970). Whitaker (1972) noted that the least shrew is unknown above 905 m (2968 ft) in the United States; however, Handley and Patton (1947) reported that in Virginia it occurs somewhat higher, "...from sea-level along the coast up to at least 3100 feet [945 m] elevation in the mountains." Suggestive of its southern affinities and its rarity at high elevations in Virginia, Pagels (unpublished) found *C. parva* at elevations ranging from 6 m to only 473 m (mean 174 m; 572 ft) in a statewide study of Virginia shrews that included 40 sampling sites above 473 m.

Whitaker (1974) summarized reports from throughout the range of the least shrew and noted that it "...inhabits grassy, weedy, and brushy fields, at least in the northern parts of its range...." Handley and Patton (1947) noted that in Virginia's coastal areas *C. parva* is most common in salt marshes. Inland, the least shrew is most common in abandoned fields, but it has also been taken in cultivated fields, thickets, and marshes (Handley and Patton, 1947). Thirty-seven of 38 specimens of *C. parva* taken at 13 localities in Pagels' statewide effort were collected in "old field" (33) or edge (4) habitats; only one forested site yielded a *C. parva*.

The tree assemblage at the Whitetop site reflected the high elevation of the area; however, the forested habitat and the species composition of the forest at the site are highly unusual for *C. parva*. Based on counts of trees with a dbh of 10 cm or greater, the site was basically a red spruce forest (*Picea rubens*, 89.4% of trees counted per ha) with occasional Fraser fir (*Abies fraseri*, 1.4%), and widely scattered hardwoods, that included black locust (*Robinia pseudo-acacia*, 2.8%), American beech (*Fagus grandifolia*, 2.8%), yellow birch (*Betula lutea*, 2.2%), and black birch (*B. lenta*, 1.4%). Moss-covered rocks and boulders up to 1.5 m in diameter were evident at the site. Mean age of 40 trees cored at the site was 106 years. Mean canopy openness at the site was 33.2 % based on 100 measurements.

The moderately open canopy, primarily the result of scattered treefall at the site, was reflected in relatively large numbers of herbs and seedlings of *P. rubens*.

The male specimen, captured in a pitfall trap in the period 2 September to 20 September 1988, was a young of the year based on negligible tooth wear. The testes were moderately enlarged (3.1 by 1.9 mm). The skull and fluid preserved body are deposited in the Virginia Commonwealth University Mammal collection (VCU 5588). Other species of shrews captured at the site in the study were the masked shrew (*Sorex cinereus*), the smoky shrew (*S. fumeus*), and the rock shrew (*S. dispar*).

ACKNOWLEDGEMENTS

I'm grateful to J. Baker and J. Haulsee for assistance in placement of the traps, and to them and M. Fics for checking of traps at the Whitetop Mountain site. H. duval and K. Uthus played valuable roles in many aspects of the study of small mammal associates of the northern flying squirrel. F. Dirrigl, Jr. graciously provided helpful comments on the manuscript. The study was supported by the Nongame Wildlife and Endangered Species Program of the Virginia Department of Game and Inland Fisheries.

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CORRECTIONS SUBMITTED

Roane, Martha K. 1991. The Grasses of Virginia. Va. J. Sci. 42:3-100.

Page 6, Couplet 4, 4'

4. Spikelets 1-flowered; pedicel jointed just below the spikelets . . . 5
 4'. Spikelets 1-to many-flowered; jointed below the spikelets in
 the pedicel, the rachis or at the base of a cluster of spikelets . . . 27

Page 10, Couplet 60, 60'

60. Low or rather tall grasses, rarely more than 1.5 m tall 63

Page 10, Couplet 61, 61'

- 61'. Leaves distributed along culms 62

Page 12, Couplet 78, 78'

78. Leaves entire, pointed, awnless or awned from the tip 79

Page 21, *Anthroxanthum*

1. Plants perennial; culms not geniculate but tufted *A. odoratum*
 1'. Plants annual; culms often geniculate and bushy
 branched *A. aristatum*

Page 28, Couplet 15, 15'

- 15' Panicle open, the branches spreading; awn to 5 cm 16

Page 33, couplet 1, 1'

- 1'. Body of bur globose, 5 or more mm wide, not tapering
 at base; plant annual 2

Page 39, Couplet 1, 1'

Change word branches to blades in 1 and 1'.

Page 40, Couplet 14, 14'

14. Lower blades cordate at base; ligule absent or a ring of hairs . . . 15
 14'. Blades not cordate at base; ligule a fringed or glabrous
 membrane *D. scabriusculum*

Page 44. Synonyms of *Dichantherium acuminatum*

Panicum lanuginosum Ell.

Panicum tennesseense Ashe

Page 45. *Dichantherium dichotomum* (L.) Gould. Forking panic. Bushy panic.

Page 55, Couplet 5, 5'

- 5'. Blades involute or, if flat, less than 3 mm wide 8

Page 55, Couplet 6,6'

6'. Spikelets ovate or oval, mostly not more than 5-flowered,
less than 1 cm long 7

Page 57, Couplet 6, 6'

6. Lemmas 3-4 mm long; panicle oblong, dense,
usually not more than 10 cm long *G. obtusa*

Page 68, Couplet 1,1'

1'. Plants perennial 9

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Eleanor Tenney

Eleanor Tenney

Eleanor Tenney, a long time member of the Academy and a former Patrick Henry High School teacher, died September 30, 1991 at her home in Richmond. Born in West Virginia, Tenney graduated from West Virginia Wesleyan with a degree in biology in 1950. She also earned a Master's degree in Education from West Virginia University. She moved to Hanover in 1957 as a teacher for Montpelier High School and transferred to Patrick Henry High School when it opened in 1959. She remained at Patrick Henry until taking early retirement five years ago. During her time at Patrick Henry, she encouraged students to pursue their interests in science and photography.

Eleanor Tenney was well known for her involvement in science. She was an honorary member of the University of Richmond Chapter of Beta Beta Beta National Honor Society in Biology. She was also a member of Alpha Delta Kappa, Beta Chapter, a national honorary society for women educators. Eleanor was a member of the Virginia Academy of Science, and at the time of her death was serving on the board for the Virginia Junior Academy of Science.

She received distinguished service awards from the Academy of Science twice and has also been recognized by Westinghouse Science Foundation for her work with the Westinghouse Science Search. She was cited by the Virginia Science and Humanities Symposium for her work with students, and was cited for having served as a sponsor for more years than any other person in the State.

In the summer of 1966, she enrolled in a pteridology course at Mountain Lake Biological Station. Her interest was sparked by an unusual freshwater fern, *Marsilea vestita*. Intrigued by the organism, she encouraged an interested student to pursue an independent research project. In the spring of 1967, the student received the Botany Award at VJAS. Each successive year, for twenty-one years, an independent research project has been presented at VJAS on *Marsilea vestita*. The organism has become synonymous with her name and with quality student projects.

Since 1959, she individually sponsored over 75 students at the Academy, and assisted with the projects of hundreds more. She was selected as a VJAS's Outstanding Teacher, served on the VJAS Committee, and photographically recorded the history of the Academy with her ever present camera.

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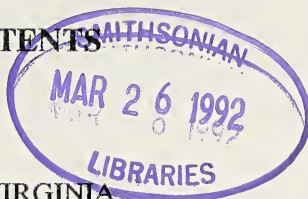
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THE VEGETATION OF VIRGINIA

A Symposium Sponsored by the Botany Section of The Virginia Academy of Science

Over ten years have passed since the first symposium on the vegetation of Virginia (organized by Frank P. Day of Old Dominion University and Terry L. Sharik of Virginia Polytechnic Institute & State University) was held at Old Dominion University in conjunction with the celebration of the tenth anniversary of the founding of the Botany Section of the Virginia Academy of Science. A number of studies relating the vegetation of Virginia have been carried out in various regions of the state since then and Steven L. Stephenson of Fairmont State College (West Virginia) and Stewart Ware of the College of William and Mary organized a second symposium on Virginia vegetation for the meeting of the Virginia Academy of Science at George Mason University in May, 1990. Eight papers were presented at that symposium. Six of those papers were subsequently submitted and accepted for publication in the Virginia Journal of Science and are presented in the present volume.

Upland Oak Forests of the Ridge and Valley Province in Southwestern Virginia

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ABSTRACT

Upland forest communities of the Ridge and Valley Province in southwestern Virginia are usually dominated by various species of oak, of which chestnut oak (*Quercus prinus*) and northern red oak (*Q. rubra*) are the most important. American chestnut (*Castanea dentata*), formerly a codominant species in the tree stratum of these communities, was almost completely eliminated during the first half of this century by the chestnut blight. Although both chestnut oak and red oak sometimes occur in nearly pure stands, the more common expression is for an admixture of various other species, including red maple (*Acer rubrum*), hickory (*Carya* spp.), black oak (*Quercus velutina*) and white oak (*Q. alba*), to be represented in the tree stratum. Throughout the region, more mesophytic communities primarily occur in sheltered ravines and coves, and hemlock (*Tsuga canadensis*)-yellow birch (*Betula lutea*)-red spruce (*Picea rubens*) communities occupy a few of the most mesic high-elevation sites.

INTRODUCTION

The purpose of this paper is to provide an overview of the general pattern of upland forest community composition for a portion of the Ridge and Valley physiographic province of southwestern Virginia. Our specific objectives are (1) to first identify and then describe the major community types consistently encountered in the particular geographic area being considered and (2) to relate the spatial distribution of these community types to the environmental complex-gradients associated with differences in elevation and topographic position. The present paper supplements previously published reports (e.g., Stephenson 1982, Adams and Stephenson 1983) of upland forest vegetation in this same area of southwestern Virginia.

THE STUDY AREA

The quantitative data upon which this paper is based were collected during the period of 1975-1986 from the Mountain Lake area of Giles County in southwestern Virginia, which is within the Ridge and Valley Province of the southern Appalachian Mountains (Fenneman 1938). The Ridge and Valley is a region of extensively folded and thrust-faulted Paleozoic strata. The general pattern is that of a more or less parallel series of elongated, often relatively level-crested ridges which run in a southwest-northeast direction. The ridges are capped with resistant quartzites, conglomerates, and sandstones; the less resistant shales and limestones have eroded away, producing the intervening valleys (Butts 1940). The underlying

geological formations of the stands sampled in the present study consist primarily of sandstones, siltstones, and shales (Haynes 1974). Climatological data from the University of Virginia Mountain Lake Biological Station (elevation 1168 m) in Giles County indicate that average monthly temperatures range from a low of -3.7°C in January to a high of 18.5°C in July. The mean annual precipitation is 134 cm (U. S. Dept. Commerce 1972-1983).

Braun (1950) included the Mountain Lake area within the Ridge and Valley Section of the Oak-Chestnut Region. The study area lies close to the western boundary of the Oak-Chestnut Region where the latter gives way to the Mixed Mesophytic Region. The major species of trees composing the forests of the ridges are various species of oak, of which chestnut oak (*Quercus prinus*) and northern red oak (*Q. rubra*) are the most important. American chestnut (*Castanea dentata*), formerly a codominant species in the tree stratum of these communities, was almost completely eliminated during the first half of this century by the chestnut blight (Stephenson 1974, 1986).

METHODS

Field Sampling

Quantitative data on vegetation and topographic variables were collected from a total of 43 forest stands in the Mountain Lake area. All of the sampled stands met the following selection criteria: (1) a relatively homogeneous unit of vegetation, (2) located in an area of essentially uniform topography, and (3) no evidence of appreciable recent (< 40 yrs) disturbance by man or other causes.

For each stand, quantitative data for the tree stratum were obtained from a single 20 by 50 m (0.1 ha) rectangular plot laid out with its long axis parallel to the contour of the slope. Species and diameter were recorded for all woody stems ≥ 10 cm DBH (diameter at breast height [1.37 m]). Topographic variables measured or determined for each stand included elevation, percent slope, slope aspect, and slope position. Slope aspect was transformed in the manner described by Beers et al. (1966). As such, a transformed aspect value is the cosine transformation of azimuth, so that 45° (NE aspect) = 2.0 and 225° (SW aspect) = 0.0. Slope position was derived subjectively from maps and field observations. An index of slope position was assigned to each stand on the basis of 1 = upper slope, 2 = mid-slope, 3 = lower slope, and 4 = ravine or cove. Identification of hickories to species was not always possible and all individuals were simply recorded as *Carya* spp. However, pignut hickory (*C. glabra*) is the most common species of hickory in the general study area. Nomenclature used for vascular plants follows that of Radford et al. (1968).

Data Analyses

Field data were converted to absolute measures. Density (number of stems per hectare) and basal area (m^2 per hectare) were determined for all species represented in the tree stratum. These data were then used to calculate species importance value indices. As used in this paper, importance values are one-half the sum of relative density and relative basal area (i.e., maximum value = 100).

Species diversity indices were calculated for the tree stratum using Shannon's formula (Shannon and Weaver 1963) and importance values as measures of species abundances. The general formula of this index is

$$\text{Species diversity } (H') = -\sum p_i \log p_i$$

where p_i is the proportion of the total for all species represented by species i . This index varies from a value of 0 for a community containing a single species to some maximum value for a community containing many species, each with a low level of importance.

A weighted average (Whittaker 1967) was calculated for each sampled stand by first assigning synthetic moisture indices (Goff and Cottam 1967) to all species represented in the tree stratum and then multiplying the importance value for each species present in that stand by the appropriate index. The synthetic moisture indices used in this study were 0 (for species usually limited to mesic sites), 1 (for species characteristic of submesic sites), 2 (for species characteristic of subxeric sites), and 3 (for species usually limited to xeric sites). Indices were assigned on the basis of the species groupings given in Whittaker (1956) and are consistent with distributional data available for other areas in the southeastern United States.

The 43 stands were subjected to Detrended Correspondence Analysis (Hill 1979, Hill and Gauch 1980), using the Cornell Ecology Program DECORANA (Hill 1979). This method of ordination was chosen because it has been shown to be relatively effective in a number of other studies (Gauch 1982). The ordination was computed using importance value indices.

RESULTS AND DISCUSSION

Vegetation and site parameters of the 43 stands sampled in the present study are summarized in Table 1. All of the stands were located at elevations > 775 m and seven occurred at elevations > 1219 m. Sampled stands occupied a wide range of topographic positions, ranging from exposed ridgetops to lower, protected slopes of ravines. Based on the average value for transformed aspect (1.1), "mesic" and "xeric" exposures were about equally represented. Total density of the tree stratum averaged 580 stems/ha and the average basal area was $28.9 \text{ m}^2/\text{ha}$. The latter figure is near the midpoint of the range reported for mature, temperate deciduous forests (25.8 to $32.2 \text{ m}^2/\text{ha}$) by Held and Winstead (1975). Mean values calculated for species diversity (H') and species richness were 2.01 ± 0.7 and 7 ± 0.3 , respectively.

Thirty species were represented in the tree stratum, but only 17 of these achieved an average (based on pooled data from all 43 stands) importance value > 0.5 and thus are included in Table 2. Red oak and chestnut oak were clearly the most important species present, with red maple (*Acer rubrum*), hickory, white oak (*Q. alba*), and hemlock (*Tsuga canadensis*) the only other species with an average importance value > 5.0 . However, hemlock was present in only six stands.

The positions of the 43 stands on the two-dimensional DCA ordination are shown in Figure 1. The first axis would seem to relate most closely to an environmental moisture complex-gradient (sensu Whittaker 1967), with stands dominated by tree species characteristic of more xeric sites located on the left side of the ordination and those dominated by species characteristically found on more mesic sites on the right side. The correlation of DCA ordination scores for the first axis and weighted averages calculated for sampled stands was highly significant ($r = 0.85$, $p < 0.01$). Because communities dominated by tree species characteristic of truly xeric sites do not occur at higher elevations in the area of Giles County sampled

TABLE 1. Summary data for vegetation and site characteristics of 43 stands sampled in the Mountain Lake area of southwestern Virginia.

Parameter	Range	Mean	± SD
Elevation (m)	775-1280	1079	± 131
Aspect*	0.1-2.0	1.1	± 0.7
Slope position**	1-4	2.1	± 1.0
Slope (%)	2-85	33	± 20
Density (N/ha)***	280-990	580	± 131
Basal area (m ² /ha)***	17.4-50.0	28.9	± 7.2
Species richness***	4-12	7	± 2.0
Species diversity (H')***	0.76-2.71	2.01	± 0.46

*aspect is cosine transformation of azimuth (Beers et al. 1966), so that 45° = 2.0 and 225° = 0.0

**1 = upper slope, 2 = mid-slope, 3 = lower slope, and 4 = ravine or cove

***stems ≥ 10 cm DBH

TABLE 2. Composition of the tree stratum (stems ≥ 10 cm DBH) for all 43 stands.

Species	Moisture index	No. of stands present	Average importance value
<i>Quercus rubra</i>	1	40	28.3
<i>Quercus prinus</i>	2	26	20.4
<i>Acer rubrum</i>	1	35	10.1
<i>Carya</i> spp.	1	26	7.2
<i>Quercus alba</i>	2	19	5.5
<i>Tsuga canadensis</i>	0	6	5.2
<i>Quercus velutina</i>	2	14	3.8
<i>Betula lutea</i>	0	5	2.6
<i>Betula lenta</i>	1	20	2.4
<i>Picea rubens</i>	0	4	2.4
<i>Robinia pseudoacacia</i>	2	19	2.3
<i>Magnolia acuminata</i>	0	18	2.2
<i>Amelanchier arborea</i>	1	15	1.2
<i>Oxydendrum arboreum</i>	2	7	1.2
<i>Acer saccharum</i>	0	6	1.0
<i>Nyssa sylvatica</i>	2	7	0.7
<i>Fagus grandifolia</i>	0	1	0.6
Other species ¹	0-3	1-5	2.9
Total			100.0

¹*Acer pensylvanicum*, *Castanea dentata*, *Cornus florida*, *Fraxinus americana*, *Hamamelis virginiana*, *Liriodendron tulipifera*, *Ostrya virginiana*, *Pinus rigida*, *Pinus strobus*, *Prunus serotina*, *Quercus coccinea*, *Sassafras albidum*, and *Tilia heterophylla*

in this study (Stephenson 1982), both the compositional gradient along the first axis and the moisture gradient to which it corresponds are truncated. Therefore, the most xeric portion of each of the two gradients is better designated as subxeric than xeric. The arrangement of stands along the second axis of the ordination appears to be most closely related to elevation ($r = 0.35$, $p < 0.05$). Most of the stands located toward the top left corner of the ordination are found at elevations > 1100 m, whereas the majority of the stands located toward the lower left are at elevations < 1100 m. However, stands located at the highest elevations actually occur near the middle of the second ordination axis and thus represent exceptions to this general pattern.

Clusters of stands sharing the same leading dominants and thus considered to represent a particular community type are encircled on the ordination (Figure 1). Average importance values for all of the more important species present in the group of stands assigned to each community type are given in Table 3. Community types are named on the basis of the major dominants; these names are provided with each community type (Figure 1). Five different clusters of stands are apparent on the ordination, although for one of these (the cluster located in the upper left corner) the degree of spatial separation of member stands indicates considerable compositional heterogeneity. In addition, one stand dominated by a tree species (beech [*Fagus grandifolia*]) not encountered in any other stand was considered compositionally unique and thus was not assigned to any of the five community types. One community type is located on the far right side of the ordination, whereas all of the others occupy positions on the left. Stands making up the former are dominated by tree species (including two conifers) generally associated with only the most mesic sites, whereas the member stands of the latter are dominated by species (mostly oaks) characteristic of submesic or subxeric sites. The lack of any distinct separation among the four community types located on the left side of the ordination is undoubtedly the result of the constancy of chestnut oak and red oak. Although stands strongly dominated by chestnut oak occurred on apparently more xeric sites than those occupied by stands in which red oak achieved a high level of dominance, the usual situation was for both species to be present. Only in stands located on the most mesic sites or at the highest elevations sampled (> 1219 m) was chestnut oak completely lacking. As a general observation, the three oak-dominated community types that fall within the lower half of the ordination form a sequence that reflects a transition in dominance from chestnut oak to red oak. Collectively, these two species are relatively less important and certain other species (particularly white oak and hickory) more important in stands making up the one community type located in the upper half of the ordination.

Information as to the elevation and general location (i.e., topographic position) of stands making up each community type is given in Table 4. Although the ranges of elevation recorded for member stands of the five community types are broadly overlapping the mean values calculated for the groups of stands representing the various community types suggest that the distribution of community types can be related to an elevation complex-gradient, with chestnut oak-black oak at the lower end of the gradient and red oak-red maple at the higher end. Moreover, when the locations of member stands of a particular community type are examined, the general pattern is for these stands to occur in roughly comparable situations with

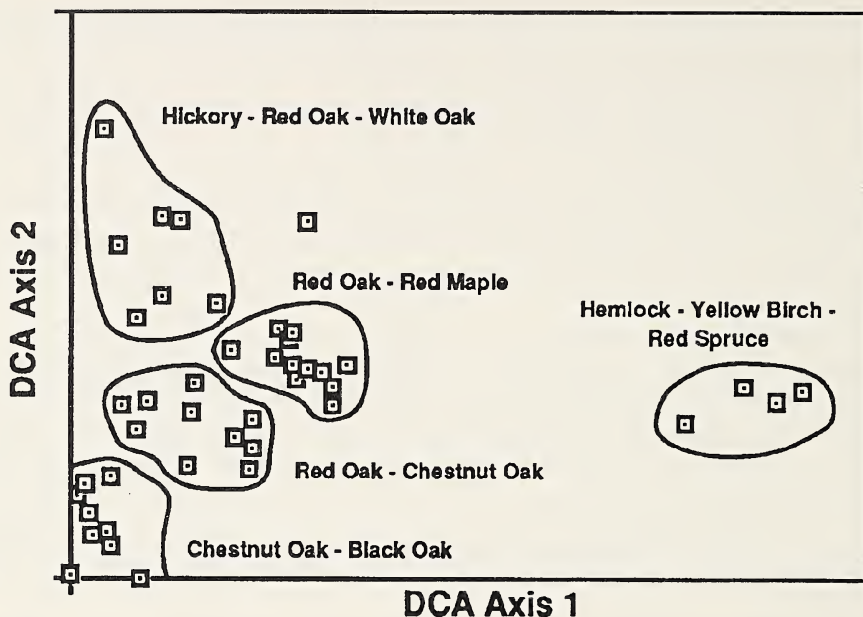


FIGURE 1. DCA ordination of sampled stands based on importance values of species represented in the tree stratum. Solid lines delimit community types named on the basis of the leading dominants.

respect to slope position and aspect. For example, stands assigned to the chestnut oak-black oak community type are nearly all on south facing slopes and most are located at lower or mid-slope positions (mean value for slope position [SP] = 2.3). Stands assigned to the hickory-red oak-white oak community type also occur on south-facing slopes, but these stands are located at mid- to upper slope positions (SP = 1.6). In contrast, all of the stands making up the hemlock-yellow birch-red spruce community type occur in ravines or coves (SP = 4.0). Mean values of slope position for stands of the red oak-chestnut oak and red oak-red maple community type were 2.3 and 1.4, respectively. The mean values of weighted averages calculated for member stands of the five community types would seem to indicate that these community types occupy clearly different situations with respect to site moisture conditions, with chestnut oak-black oak (mean value = 177) as the most xeric and hemlock-yellow birch-red spruce (mean value = 36) as the most mesic. Mean values for the red oak-chestnut oak, hickory-red oak-white oak, and red oak-red maple community types were 144, 128, and 101, respectively. The one stand not assigned to any community type (Figure 1) had a weighted average of 49, which is well within the range of values (5-74) calculated for the most mesic of the five community types. On this basis, this stand would be considered just as mesophytic. The main reason it does not occur close to the stand cluster considered to represent a hemlock-yellow birch-red spruce community type on the ordination is that it lacks the appreciable coniferous component that the member stands of this cluster share in common. In fact, this one stand would appear to represent a relatively high-elevation example of the mixed mesophytic community type as described by Braun (1950) for other areas of the Appalachian Mountains. McCormick and Platt (1980)

TABLE 3. Composition of the tree stratum (stems ≥ 10 cm DBH) for the five community types. Figures given are average importance values for all stands in each community type. Number of stands in each type is shown in parentheses under each type name.

Species	Community Type				
	Chestnut oak- black oak (9)	Red oak- chestnut oak (10)	Hickory- red oak- white oak (7)	Red oak- red maple (12)	Hemlock- yellow birch- red spruce (4)
<i>Quercus rubra</i>	5.5	29.8	23.0	57.8	0.9
<i>Quercus prinus</i>	54.8	28.8	9.2	1.4	-
<i>Acer rubrum</i>	7.0	12.0	4.0	16.7	3.7
<i>Carya</i> spp.	6.6	4.8	28.7	1.3	-
<i>Quercus velutina</i>	13.5	4.2	0.6	0.2	-
<i>Quercus alba</i>	1.8	8.0	18.5	3.2	-
<i>Betula lenta</i>	-	2.3	0.8	4.6	5.7
<i>Magnolia acuminata</i>	0.4	2.0	1.4	4.6	0.4
<i>Robinia pseudoacacia</i>	3.2	2.7	4.6	0.9	-
<i>Tsuga canadensis</i>	-	-	-	-	42.6
<i>Picea rubens</i>	-	-	-	0.2	18.1
<i>Betula lutea</i>	-	-	0.7	0.6	23.2
<i>Amelanchier arborea</i>	-	0.4	0.5	3.7	0.7
<i>Oxydendrum arboreum</i>	2.9	0.4	2.1	-	-
<i>Acer saccharum</i>	0.7	-	4.7	0.9	-
Other species	3.6	4.6	1.2	3.9	4.7
Total	100.0	100.0	100.0	100.0	100.0

reported that mixed mesophytic communities dominated by such species as basswood (*Tilia americana*), buckeye (*Aesculus octandra*), black birch (*Betula lenta*), and white ash (*Fraxinus americana*) occur at elevations < 850 m on the relatively mesic lower slopes of Beanfield Mountain, which is within the general study area. However, with the possible exception of this single example, stands representing a mixed mesophytic community type were not encountered in the present study and thus would seem to be relatively uncommon at the elevations we sampled. Nevertheless, the fact that we have designated the most mesic expression of upland forest vegetation in the Mountain Lake area as "hemlock-yellow birch-red spruce" should not be interpreted as meaning that other types of mesophytic communities having a rather different composition do not exist. It should be noted that the occurrence of mixed mesophytic communities at even higher elevations in the Balsam Mountains of extreme southwestern Virginia was reported by Rheinhardt and Ware (1984).

Based on the mean value of species diversity (H') calculated for the group of stands assigned to each of the five community types, the red oak-chestnut oak ($H' = 2.17$) and hickory-red oak-white oak ($H' = 2.14$) community types were

TABLE 4. Summary data on the five community types.

Community type	Elevation (m)		Location
	Range	Mean	
Chestnut oak-black oak	775-1125	962	Lower to mid-slope
Red oak-chestnut oak	855-1110	1016	Lower to mid-slope
Hickory-red oak-white oak	900-1145	1068	Mid-slope to upper slope
Hemlock-yellow birch-red spruce	1051-1170	1123	Ravines and coves
Red oak-red maple	1095-1280	1204	Mid-slope to upper slope

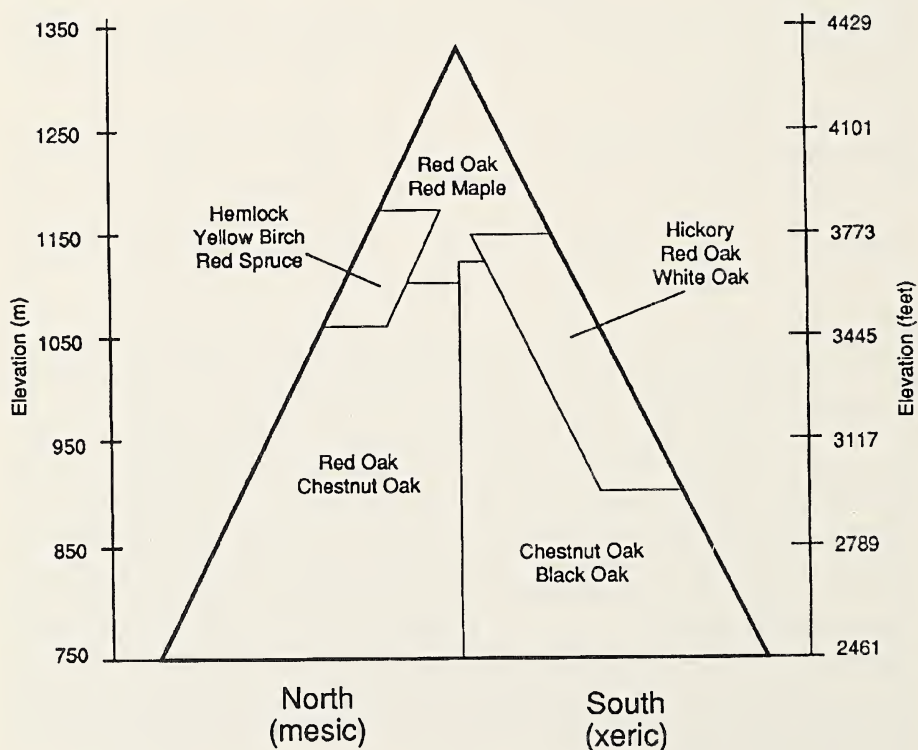


FIGURE 2. Generalized diagram showing the spatial distribution of the five major community types recognized in this paper.

characterized by the highest diversity, whereas the red oak-red maple community type was characterized by the lowest diversity ($H' = 1.80$). The values obtained for the hemlock-yellow birch-red spruce and chestnut oak-black oak community types were $H' = 1.89$ and $H' = 1.95$, respectively.

The spatial relationships of the five community types, as indicated by the information presented in Table 4, are graphically illustrated in Figure 2. It should be pointed out that this model is very general and also based upon quantitative data on forest community composition from just one portion of the Ridge and Valley province. Because the Ridge and Valley is so geologically and topographically heterogeneous, it is characterized by a relatively diverse pattern of vegetation. As such, the applicability of the model to the upland forest vegetation of the entire region is questionable. Nevertheless, the data presented herein do suggest that it is possible to identify relatively well-defined community types and to elucidate vegetation-environment relationships for at least a specific topographic area.

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Environmental Threats to the Health of Montane Forests of Northwestern Virginia

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ABSTRACT

Recent studies of forest decline have raised the question of how environmental stressors interact to affect the health of forest ecosystems. I provide an overview of the major environmental stressors on the health of montane forests in northwestern Virginia, and suggest that additional information on factors affecting forest health would enhance future studies of forest ecology.

INTRODUCTION

Recent studies of forest decline have raised the question of how environmental stressors interact to affect the health of forest ecosystems. While in the past the emphasis has typically been on "single biotic or abiotic primary-causal-agent diseases" (Manion 1981), it appears that many disease syndromes observed today (at least in natural ecosystems) may in fact be caused by combinations of causal agents that interact in various ways to produce the symptoms observed.

In this paper I present an overview of the major environmental factors affecting the health of montane forests in northwestern Virginia, and suggest that additional information on the distribution and importance of environmental stressors affecting forest health would be a valuable contribution to both studies of disease syndromes and forest ecology in general.

METHODS AND MATERIALS

Sources

Most of the data used in this study comes from published literature, most notably Brown (1986), Garner et al (1989), Huber et al (1987) and Smith and Tirpak (1989). Where necessary, the available data is supplemented by information based on interviews with National Park Service and USDA Forest Service personnel and by personal observations during field excursions through the area. Most of the forest composition and tree damage information is based on the fifth USDA Forest Service Forest Inventory and Analysis (FIA) survey of Virginia, conducted during 1984-1985.

Approach

I divided the types of factors affecting forest health in northwestern Virginia into three types: non-anthropogenic factors, anthropogenic factors, and fire. Non-anthropogenic factors include competition, weather, insects, diseases, browsing, and senescence. Anthropogenic factors include air pollution, real estate and industrial development in forested areas, and anthropogenically-induced climate

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change. Fire is treated as a separate case because it can result from either natural causes or by human activities.

The Study Area

The area under consideration is the Northern Mountains region of Virginia as defined by the USDA Forest Service (Bechtold et al 1987, Brown 1986). The region is composed of Alleghany, Augusta, Bath, Botetourt, Clarke, Craig, Frederick, Highland, Page, Roanoke, Rockbridge, Rockingham, Shenandoah and Warren Counties (Brown 1986). Most of Shenandoah National Park and the George Washington National Forest and some of the Thomas Jefferson National Forest lie within the study area.

There were 2.5 million acres of timberland in the region as of 1985. Of that, approximately 10% of the stands were classified as softwood types and 90% as hardwood types (Brown 1986). The major forest cover types are shown in Table 1. The more important species (or species groups as defined in Huber et al 1987) are shown in Table 2. Only those species which made up at least 1% of the region's total tree population are considered.

DISCUSSION

Non-Anthropogenic Factors¹

The major non-anthropogenic factors affecting forest health in the region are: 1) competition and site conditions; 2) weather; 3) insects; 4) fungi and other pathogens; 5) overbrowsing; and 6) senescence.

Suppression and stagnation as a result of strong competition and/or poor growing sites is a major cause of damage in many softwood and hardwood species in the region, affecting over 5 percent of the trees in the sapling size class (Huber et al 1987).² Softwood species are more seriously affected, with over 10 percent of the saplings affected in Virginia pine, pitch pine and table mountain pine.

Weather (excluding lightning), is a major cause of damage in all species except white and chinkapin oaks, hickories and Virginia pines (Huber et al 1987). Trunk and branch breakage due to wind and ice, and visible damage (frost cracks, winter burn, etc.) from temperature extremes are typical examples of weather damage.

Weather events, such as serious droughts, can help trigger diebacks, especially in trees growing in unfavorable sites. Dieback, while affecting all hardwoods, is a major cause of damage only in larger-size oaks (Huber et al 1987).

Insects are widespread in the forests of the region but, at least until recently, caused visible damage to only a small percentage of trees. At the time when the data reported in Huber et al (1987) were gathered (1984 and 1985), only hardwood borers, which primarily affect red/black oaks (northern red, scarlet, southern red, and black oaks) and maples (red, silver, and sugar maples), and terminal shoot and

1 Statistics based on data from Huber et al. (1987) are for the entire state of Virginia instead of the region of concern in this paper. However, the species (or species groups) discussed in this section are among the more important members of the region's forest communities as defined earlier.

2 The size classes (after Huber et al. 1987) are as follows: Sawtimber (≥ 9.0 inches DBH for softwoods, ≥ 11 inches DBH for hardwoods); Poletimber (≥ 5 inches DBH but smaller than sawtimber size); Saplings (1 to 5 inches DBH).

TABLE 1. The major forest cover types in northwestern Virginia (after Brown, 1986).

Forest type	Total Acreage	Percent of Region's Total Timberland
Oak-Hickery	1,702,000	67%
Oak-Pine	284,000	11%
Chestnut Oak	226,000	9%
Virginia Pine	94,000	4%
Pitch Pine	60,000	2%
Table Mountain Pine	43,000	2%
White Pine-Hemlock	43,000	2%

TABLE 2. The more important trees species (based on the number of live trees) in northwestern Virginia (after Brown, 1986).

Common Name	Scientific Name	Percent of Region's Tree Population
Red and silver maples	<i>Acer rubrum</i> , <i>A. saccharinum</i>	13%
Blackgum	<i>Nyssa sylvatica</i>	12%
Chestnut oak	<i>Quercus prinus</i>	10%
Hickory	<i>Carya</i> spp.	7%
Scarlet, southern red and black oaks	<i>Quercus coccinea</i> , <i>Q. falcata</i> , <i>Q. velutina</i>	6%
Virginia pine	<i>Pinus virginiana</i>	4%
White and chinkapin oaks	<i>Quercus alba</i> , <i>Q. muehlenbergii</i>	4%
Eastern white pine	<i>Pinus strobus</i>	4%
Northern red oak	<i>Quercus rubra</i>	3%
Yellow poplar	<i>Liriodendron tulipifera</i>	2%
Black locust	<i>Robinia pseudoacacia</i>	2%
Pitch pine	<i>Pinus rigida</i>	2%
Sugar maple	<i>Acer saccharum</i>	1%
Table mountain pine	<i>Pinus pungens</i>	1%
Eastern hemlock	<i>Tsuga canadensis</i>	1%
Ash	<i>Fraxinus</i> spp.	1%

stem borers, which primarily affect hickories, were major causes of damage to trees in the region.

The incidence of damage from bark beetles may have been under-reported in Huber et al (1987) because, as the authors pointed out, death of the tree generally occurs within a few years of infestation by the beetles, and dead trees would not have been counted in the forest survey.

The gypsy moth has been appearing in increasing numbers and has begun to defoliate thousands of acres in the area, particularly in the northern and eastern

portions (such as the Blue Ridge). Most of the area falls within the area where 51-75% of the timber is susceptible to defoliation by gypsy moths (Huber et al 1982). The long-term effects of the gypsy moth on forest composition in the region are unknown.

Fungi and other pathogens have had major impacts in the region in the past. The chestnut blight has virtually wiped out the American chestnut, which had been a major component of the forests in the region. Most chestnut sprouts in the area are infected to some extent.

All species groups display a significant number of form defects due to unknown causes, at least in the smaller size classes (Huber et al 1987). Basal defects are prevalent only among hardwood species, except for some oaks and yellow poplar. It is probable that fungi and other pathogens are involved to some extent in the processes leading to these defects. Form and basal defects may also give some indication of the stress level faced by the forests in the region, at least by suggesting the prevalence of damaging agents.

Portions of the region are subject to overbrowsing by white-tail deer. This is especially apparent in protected areas such as in Shenandoah National Park, where a striking browse line can be observed from many areas along Skyline Drive. The overbrowsing problem is primarily restricted to forests within one mile of human development (David Haskell, Shenandoah National Park, *personal communication*).

The age of the forests in the area is increasing (Brown 1986). The frequency of declines may increase due to senescence alone, or as a result of increasing susceptibility of older trees to environmental stresses (Franklin et al 1987, Manion 1981, Mueller-Dombois 1987).

Anthropogenic Factors

The major anthropogenic factors either affecting or having the potential to affect the health of forests in the region are: 1) air pollution; 2) development; and 3) climate change.

Air pollution may affect plants either directly by damaging plant tissues (e.g. Paparozzi and Tukey 1984) or indirectly through mechanisms such as interfering with the cold hardening process (Friedland et al 1984) or by altering the soil chemistry, leading to the increase of elements like aluminum to phytotoxic levels (Ulrich et al 1980).

Most of the region falls in the area labelled as facing minimal risk to the effects of wet deposition of acidic pollutants (Buikema et al 1988), however, areas of moderate risk occur along the Blue Ridge and on higher portions of the ridges to the west. Typically, the pH of rainwater is not low enough to cause acute toxic effects to foliage. However, potential effects on forest ecosystems due to soil-mediated processes cannot be ruled out. Gaseous ozone (and some other photochemical oxidants) occurs in concentrations high enough over most of the eastern United States to cause foliar injury to sensitive species, inhibit photosynthesis, alter carbon allocation and affect mycorrhizal associations (Garner et al 1989, Gilliam et al 1989).

Pollutants in the environment typically occur in mixtures. It has been demonstrated that pollutants in mixtures, such as sulfur dioxide and ozone, may act

synergistically, resulting in increased toxic effects on vegetation beyond those predicted on the basis of each pollutant occurring in isolation (Carlson 1979, Chappelka et al 1985, Chevone et al 1986, Garner et al 1989, Mansfield and Freer-Smith 1981).

Forests at higher elevations (> 1,000 meters) may be especially susceptible to damage from pollutants in cloud water and fog. The area experiences heavy fogs at least 60 days per year (Barchet et al 1988), with the frequency increasing with altitude. Sigmon et al (1989) found that cloud water averaged four times more acidic than precipitation at Shaver Hollow in Shenandoah National Park. Under those conditions the concentrations of pollutants are more likely to reach levels comparable to those that cause visible injury to plants in laboratory and greenhouse studies.

Stagnation events caused by high-pressure systems over the region may result in an increase in the concentration of air pollutants in the region, resulting in acute toxicity effects. While stagnation events often occur over the entire region, it is likely that the forests in the smaller valleys in the western part of the region would be most affected.

Although much of the timberland in the region is protected on public lands, the loss of forested land (in addition to agricultural land) is still a cause of concern. According to Brown (1986), urban and related uses claimed 50% of the acreage diverted from timberland during the period from 1977 to 1985. My personal observation is that there has been increasing development pressure on the forest and rural land in the northern part of the region. Development pressure in the area will probably fluctuate periodically depending on the health of the real estate market, especially in the Washington, D.C. metropolitan area.

There is the potential for drastic disruptions of the forest communities if global warming occurs. Several climate models predict an increase in temperature and in the frequency of drought in the southeastern United States (Urban and Shugart 1989). Such changes could make the climate of northwestern Virginia more suitable for species with a higher temperature and drought tolerance and lead to decreased productivity in the region's forests. Changes in the region's climate may also influence the disturbance regime (including fire frequency and magnitude) as well as the activity of insects and pathogens (Smith and Tirpak 1989, Woodman and Furiness 1989).

Assuming the projections for increased temperature and drought frequency are correct, the forest communities of the region could experience a northward migration of species (Urban and Shugart 1989). An analogous shift would occur along an elevational gradient as well, with upper and lower distribution limits migrating higher on mountain slopes for many species. Indeed, some montane community types that are limited in extent in the region, particularly spruce-fir communities on the higher elevations in the Blue Ridge and Ridge and Valley Provinces, could disappear entirely (Woodman and Furiness 1989). If the climate warms faster than forest species can extend their range northward in response, many species may become extinct (Zabinski and Davis 1989). The potential for local extinction will be much higher in fragmented habitats.

As for the more widespread community types in the region, there is likely to be a shift from oak-hickory to oak-pine to yellow pine community types (Urban and

Shugart 1989). Some areas facing severe drought stress (or increasing wildfire frequency) could even shift to an open savannah or even grassland community, although these would most likely be limited in extent in the region.

Fire

Fire is a complex phenomenon that warrants special treatment. Human and non-human factors can interact to affect the behavior of specific fires in various ways, and the relative importance of human and non-human factors in controlling the fire regime prior to European arrival cannot be assessed with any degree of certainty.

An average of 55 fires a year burn in the George Washington National Forest (Boyd Ritchie, George Washington National Forest, *personal communication*). Most fires range in size from one to 100 acres, and the average size of a fire in the George Washington National Forest is 11-14 acres. The fires are most widespread in mixed pine-hardwood stands, but can occur in any forest type. Most result from human activity.

Shenandoah National Park experiences from 1 or 2 fires in wet years to 6 to 10 fires during drought years (David Haskell, Shenandoah National Park, *personal communication*). Most fires are rather small, but about once in every 10 years a fire will burn at least 200 or 300 acres. As in the George Washington National Forest, most fires in the park are caused by humans.

CONCLUSIONS AND RECOMMENDATIONS

The montane forests of northwestern Virginia are subject to a myriad of environmental stresses. It is important to have an appreciation of the complex interactions between environmental stresses and forest communities, especially at times like these when the forests are facing periods of potentially drastic change.

We can not afford to evaluate the effects of a particular environmental factor on the health of forests without considering the interactions of that factor with other factors simultaneously affecting the forests. Trees affected by one stressor, such as an air pollutant, are more susceptible to attack and damage from another, such as bark beetles. Air pollutants, climate extremes, increased competition, and other diseases have all been shown to affect trees in this way (Franklin et al 1987, Manion 1981, Matson and Waring 1984, Shigo 1985, Wargo 1972, Waring 1985, 1987).

Increasing fragmentation of the forest cover from urban and rural development may result in a decrease in the area available for interior forest species, resulting in more stressful living conditions for these species and leading to increased susceptibility to attack from insects and diseases and to dieback and decline syndromes. Decreasing stand size may also render some stands susceptible to total destruction by larger-scale disturbances. If preservation of critical habitats is a priority, then management policies requiring forested buffers around critical habitats such as wetlands should be planned and implemented with this concept in mind.

As fragmented habitats may also inhibit the migration abilities of forested species, policies should be planned now in order to ensure that sufficient migration corridors exist should climate warming begin to affect the distribution of species in the region's forest communities.

More information on the distribution and magnitude of factors affecting forest health, gathered from observations made during field studies, is needed. I will use an example from my own research to illustrate how such information can be efficiently gathered in the field. I must point out, however, that the documenting stress levels in the forests is not the primary focus of my current research. The methods I describe are just ways that I can efficiently gather information on stress levels in addition to acquiring the primary data I desire.

I am measuring forest community composition in 20x50-meter quadrats on two mountains in the Ridge and Valley Province. In addition to measuring the diameter at breast height (DBH) of live trees, I also measure the DBH of standing dead trees. I also try to identify the dead trees. This information will provide some insight on how the community has been changing (or not) during recent years. I also note evidence of damage and evidence of potentially damaging agents (such as the presence of gypsy moth egg masses) on living trees as I measure them.

I also look for remaining signs of disturbance (such as fire, windthrow, or mass movements) which affected the stand in the past. This additional data, which doesn't add much to the time spent on a site, will help me understand how the present composition of the community has evolved.

Increased effort should be made to report such information in the ecological literature. More information, and/or more communication of such information among researchers, could be a great help in building our understanding of forest ecology in a constantly fluctuating environment.

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High Elevation Coniferous Forests in Virginia

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ABSTRACT

Red spruce (*Picea rubens*), the most characteristic species of the subalpine coniferous forests which occupy higher peaks and ridges of the Appalachian system from Maine to Tennessee and North Carolina, has a rather restricted distribution in the mountains of central and southwestern Virginia. The approximate lower limit for red spruce in Virginia is 975 m, although well-developed spruce communities generally do not occur at elevations below 1200 m. Indigenous communities of red spruce exist at no more than about a dozen localities, and at only two of these (Mount Rogers and Whitetop Mountain) is the species relatively abundant. Balsam fir (*Abies balsamea*), commonly present as a codominant species with red spruce in the northern Appalachians, reaches its southernmost limit in the Blue Ridge of northern Virginia, whereas Fraser fir (*A. fraseri*), which has a comparable ecological role in the southern Appalachians, reaches its northernmost limit on Mount Rogers in southwestern Virginia. Values of basal area and density (stems ≥ 10 cm DBH) for these communities range from 36 to 56 m²/ha and from 390 to 1320 stems per ha, respectively.

INTRODUCTION

Red spruce (*Picea rubens*), the most characteristic species of the subalpine coniferous forests which occupy higher peaks and ridges of the Appalachian system from Maine to Tennessee and North Carolina, has a rather restricted distribution in the mountains of central and southwestern Virginia. Presumably, this is because few areas in the region reach the elevations necessary to provide the cool, moist conditions required for the development of this community type. At present, the approximate lower limit for spruce in central and southwestern Virginia is 975 m, although well-developed spruce communities generally do not occur at elevations below 1200 m. Today, indigenous communities of red spruce exist at no more than about a dozen localities in central and southwestern Virginia (Hoffman 1950, Mazzeo 1966, Adams and Stephenson 1984) and at only two of these (Mount Rogers and Whitetop Mountain in extreme southwestern Virginia) is the species relatively abundant. Balsam fir (*Abies balsamea*), commonly present as a codominant species with red spruce in the northern Appalachians, reaches its southernmost limit in the Blue Ridge of northern Virginia (Adams and Stephenson 1985). There it occurs primarily as a minor understory component in a few stands dominated by red oak (*Quercus rubra*). Fraser fir (*A. fraseri*) reaches its northernmost limit on Mount Rogers where it occurs as a dominant overstory component at the highest elevations (Stephenson and Adams 1984).

The isolated spruce communities in the mountains of central and southwestern Virginia have never been studied intensively. The only available quantitative data are provided by Shields (1962), Stephenson and Adams (1984), and Rheinhardt (1984), all of whom focused on the spruce-fir communities of Mount Rogers and adjacent areas, and Bailey and Ware (1990), who studied the spruce forests of Highland County. For the most part, the only published information on the spruce communities that exist at other Virginia localities is found in brief notes (e.g., Chappell 1972).

The objectives of the present study were to obtain quantitative data on the composition and structure of the vegetation at each of the Virginia localities where the red spruce community type occurs and to determine the general characteristics of the soils associated with these communities.

THE GENERAL STUDY AREA

The high-elevation areas in the mountains of central and southwestern Virginia where indigenous communities of red spruce occur include portions of both the Blue Ridge and Ridge and Valley physiographic provinces of the southern Appalachian Mountains (Fenneman 1938). The mountain ridges of the Ridge and Valley Province, which generally run in a southwest-northeast direction, form a relatively narrow belt along the western boundary of Virginia. These ridges are rather level-crested, often with steep slopes, and are usually capped with Clinch (Tuscarora) sandstone of Silurian age. The less resistant (mostly Ordovician) shales and limestones have eroded away, producing the intervening valleys. Elevations in the region generally range from 300 to 1050 m, but many ridgetops exceed 1,200 m and a few reach heights in excess of 1,375 m.

The mountains of the Blue Ridge are located to the east of the Ridge and Valley Province and consist of two rather distinct sections separated by the Roanoke River, the southernmost stream cutting through this ridge system. The northern section, separated from the ridges of the Ridge and Valley by the broad, flat Shenandoah Valley, is an irregular range of relatively rugged, broad-topped mountains which only occasionally exceed 1,200 m. The southern section consists of an elevated plateau which is deeply cut by stream valleys. The highest mountains in Virginia occur in this section of the Blue Ridge, with two peaks (Mount Rogers and Whitetop) exceeding 1,680 m. The Blue Ridge is composed primarily of metamorphosed igneous rocks.

Climatological data for high-elevation areas in the mountains of central and southwestern Virginia are limited, but data from a U.S. Weather Bureau station established in November 1971 at the University of Virginia Mountain Lake Biological Station (elevation 1,168 m) in Giles County, Virginia, give some indication of the climate of the general study area. The average annual precipitation, based on the period of 1972-1983, is 136.3 cm. The average monthly precipitation ranges from a low of 8.9 cm in August to a high of 14.8 cm in June. The mean annual temperature is 8.1°C. Average monthly temperatures range from a low of -3.7°C in January to a high of 18.5°C in July. The lowest temperature of record is -31.7°C, and the record maximum temperature is 31.1°C. The average frost-free season is about 142 days (U.S. Dept. Commerce 1972-1983).

MATERIALS AND METHODS

Quantitative data on vegetation and topographic variables were collected during the 1982-1984 field seasons for twenty-four spruce stands at fifteen localities in western Virginia (Table 1). Criteria for selection of the unit of vegetation (stand) actually sampled were that: (1) vegetation be relatively homogeneous (with respect to floristics and plant structure) and at least one hectare in size; (2) topography of the area be uniform; (3) there be no obvious evidence that a major disturbance (e.g., logging, fire, windthrow) had occurred during the lifetime of the trees sampled; and (4) red spruce be present in the canopy. Slope inclination and aspect were recorded at several locations within each stand and elevation was estimated using USGS 7.5 minute quadrangle maps, benchmarks, and obvious topographic features.

In each stand, diameters at breast height (1.37 m above ground level and hereafter referred to as DBH) of all live stems of trees (≥ 2.5 cm DBH) were recorded by species in a single 20 m by 50 m (0.1 ha) quadrat. Estimates of percent cover of herbaceous plants, exposed rock, woody debris, and bryophytes were recorded from ten 1 m by 1 m quadrats spaced at 5 m intervals along the tape. All cover values were estimated using a cover class rating scale described by Daubenmire (1968).

Quadrat data were used to calculate relative basal area and relative density values separately for size classes designated as large trees (stems ≥ 10 cm DBH) and small trees (stems < 10 cm DBH but ≥ 2.5 cm DBH). For each stand, species importance value indices for large trees and small trees were calculated as one-half the sum of relative basal area and relative density. Relative cover was determined for herbaceous plants, bryophytes, woody debris, and exposed rock.

At each locality, cores were extracted at breast height from at least five representative canopy-height red spruce to determine their approximate ages. Heights of these same trees were determined with a clinometer. After cores were air dried, glued in grooved boards, and sanded, growth rings were counted using a binocular microscope.

At least four soil samples were collected from the upper 10 cm in each stand, mixed thoroughly, and sealed in plastic bags to prevent water loss. In the laboratory, these were weighed, oven-dried at 100°C for 48 hours, and reweighed. Samples then were passed through a 2-mm sieve to remove gravel. Soil moisture was calculated as a percentage of the dry weight of the fraction less than 2-mm (Reinhart 1961). Soil pH was determined in a 1:1 soil:water mixture with a glass electrode pH meter; organic matter was determined by loss on ignition (Cox 1990); and soil texture was analyzed with the Bouyoucos hydrometer method (Bouyoucos 1951). Later, analyses of content in parts per million for phosphoric acid, calcium, magnesium, potassium, zinc, nitrate nitrogen, manganese, and total soluble salts were conducted by the Soil Testing Laboratory at Virginia Polytechnic Institute and State University, using procedures outlined by Donohue and Friedericks (1984).

Vascular plant nomenclature follows Radford et al. (1968).

TABLE 1. Locations of 24 red spruce stands sampled in western Virginia.

County	No. of Stands	Locality
Giles	1	Little Spruce Bog near Mountain Lake
Giles	1	Mann's Bog
Giles	1	War Spur Ridge
Grayson	1	Flat below summit of Whitetop Mountain
Grayson	2	Summit of Whitetop Mountain
Highland	1	Bearcamp Knob
Highland	1	Near WV state line south of US Route 250
Highland	1	Sounding Knob Lookout Tower
Highland	1	Tamarack Ridge
Madison	1	Limberlost area of Shenandoah NP
Rockingham	1	Shenandoah Mountain
Russell	3	East end of Beartown Mountain
Russell	2	West end of Beartown Mountain
Smyth/Grayson	5	Summit of Mount Rogers
Tazewell	2	Southwest rim of Burkes Garden

RESULTS AND DISCUSSION

Vegetation and site characteristics of the twenty-four red spruce stands we sampled in western Virginia are summarized in Table 2. Elevation ranged from 983 m at Limberlost in Shenandoah National Park to 1726 m at Mount Rogers. Slopes on which sampled stands occurred varied considerably in aspect, but none were particularly steep. Measured red spruce trees varied in mean height from 32.4 m at War Spur (in Giles County) to 16.3 m at Mount Rogers (the highest elevation). Based on ring counts from cored red spruce trees, most stands presumably are second-growth, although the stand at War Spur apparently has never been cut and thus can be considered as old-growth. Basal area of large trees, which ranged from 35.6 m²/ha to 55.5 m²/ha, was relatively high when compared to hardwood stands in the same region (Adams and Stephenson 1983, Rheinhardt and Ware 1984, Stephenson and Adams 1989). Density values (N/ha) (390-1320) were similar to those reported for hardwoods, although the War Spur stand (390) was relatively low (as would be expected since this is an old-growth stand). Bryophyte and herb cover varied considerably, but generally were higher than values for hardwood stands in the mid-Appalachians (Stephenson 1988, Stephenson and Adams, unpublished data). Species richness of vascular plants was lowest (13) at War Spur (the old-growth stand), and highest (43) at Limberlost (the stand located at the lowest elevation).

Twenty-one species were represented in the large tree stratum (Table 3), but only four (red spruce [IV = 59.8], Fraser fir [IV = 16.6], hemlock (*Tsuga canadensis*) [IV = 6.7], and yellow birch (*Betula lutea*) [IV = 6.6]) had average importance values exceeding 5.0. Red spruce is clearly the dominant species. Although Fraser fir was the second leading dominant overall, it occurred only in the five stands sampled at Mount Rogers, where it was the most important species. Hemlock occurred at only seven localities (9 stands), but was very important at four of these

TABLE 2. Summary data for vegetation and site characteristics of 24 red spruce stands sampled in western Virginia.

Parameter	Range	Mean \pm SD
Elevation (m)	983-1726	1376 \pm 244
Aspect ¹	0.0-2.0	1.1 \pm 0.7
Slope (%)	3-38	16 \pm 10
Canopy height (m)	16.3-32.4	21.6 \pm 4.4
Stand age (yr)	54-215	92 \pm 38
Basal area (m ² /ha ²)	35.6-55.5	46.1 \pm 6.7
Density (N/ha) ²	390-1320	834 \pm 336
Basal area (m ² /ha) ³	0.18-4.06	1.34 \pm 0.85
Density (N/ha) ³	50-1740	529 \pm 414
Bryophyte cover (%)	1-66	28 \pm 23
Herb cover (%)	<1-173	56 \pm 56
Exposed rock (%)	0-9	3 \pm 4
Dead wood (%)	1-25	12 \pm 7
Species richness	13-43	22 \pm 8

¹Cosine transformation of azimuth (Beers et al. 1966), so that 45° = 2.0 and 225° = 0.0²Stems \geq 10 cm DBH³Stems 2.5 - 9.9 cm DBHTABLE 3. Composition of the large tree stratum (stems \geq 10 cm DBH) for all 24 stands.

Species	Number stands present	Basal area (m ² /ha)	Relative basal area (%)	Density (N/ha)	Relative density (%)	Importance value
<i>Picea rubens</i>	24	29.2	63.3	470	56.3	59.8
<i>Abies fraseri</i>	5	6.7	14.5	155	18.6	16.6
<i>Tsuga canadensis</i>	9	3.6	7.8	47	5.6	6.7
<i>Betula lutea</i>	19	2.8	6.1	60	7.2	6.6
<i>Acer rubrum</i>	13	1.1	2.4	25	3.0	2.7
<i>Betula lenta</i>	10	0.6	1.3	18	2.2	1.8
<i>Fagus grandifolia</i>	5	0.5	1.1	14	1.7	1.4
<i>Sorbus americana</i>	4	0.3	0.6	18	2.2	1.4
<i>Amelanchier arborea</i>	8	0.4	0.9	10	1.2	1.0
Other species ¹	1-4	0.9	2.0	17	2.0	2.0
Total		46.1	100.0	834	100.0	100.0

¹Includes *Quercus rubra* (4 stands), *Acer spicatum* (3), *Prunus serotina* (3), *Hamamelis virginiana* (2), *Nyssa sylvatica* (2), *Acer saccharum* (1), *Carya tomentosa* (1), *Fraxinus pennsylvanica* (1), *Liriodendron tulipifera* (1), *Magnolia acuminata* (1), *Pinus strobus* (1), *Sassafras albidum* (1)

(War Spur, Mann's Bog, Little Spruce Bog [all in Giles County], and Limberlost). Yellow birch (12 stands) and red maple (*Acer rubrum*) (13 stands) were each present at 12 of the 15 localities we studied. The lowest importance values for red spruce were recorded at Mann's Bog and Limberlost, where hemlock and yellow birch shared dominance.

TABLE 4. Average importance values for species represented in the large tree stratum (stems ≥ 10 cm DBH) of each red spruce community subtype.

Species	Red Spruce Community Subtype		
	Fraser fir-Spruce ¹ (n = 5)	Hemlock-Spruce ("Bog") ² (n = 4)	Spruce-dominated ³ (n = 15)
<i>Picea rubens</i>	23.2	20.5	80.2
<i>Abies fraseri</i>	71.3	-	-
<i>Tsuga canadensis</i>	-	43.1	1.1
<i>Betula lutea</i>	1.2	19.8	6.1
<i>Acer rubrum</i>	-	3.7	4.0
<i>Betula lenta</i>	-	5.7	1.7
<i>Fagus grandifolia</i>	-	-	2.7
<i>Amelanchier arborea</i>	-	0.2	1.8
Other species	4.3	7.0	2.4
Total	100.0	100.0	100.0

¹All stands located on Mount Rogers²One stand at SNP; three stands in Giles County³All other stands

Three general subtypes of the red spruce community type can be distinguished on the basis of large tree composition (Table 4). The first of these is the forest community subtype found only at Mount Rogers; this is characterized by the presence of Fraser fir, which is absent from all other localities. The second community subtype is the hemlock-spruce forest in which hemlock typically dominates. This community type may be best described as a "bog" type, since it occupies very moist sites (e.g., Mann's Bog, Limberlost). The final community subtype is dominated by spruce (e.g., Whitetop summit) but may have an admixture of various hardwoods (e.g., Tazewell County); it characteristically occurs on summits or drier side slopes.

Twenty-two taxa of small trees were present in the stands we sampled, including five taxa not recorded as large trees (Table 5). Four are typically considered as understory trees: mountain holly (*Ilex ambigua*), hawthorn (*Crataegus* sp.), mountain maple (*Acer spicatum*), and alder (*Alnus serrulata*). The one potential canopy species was chestnut oak (*Quercus prinus*). Four species (black cherry [*Prunus serotina*], white pine [*Pinus strobus*], sassafras [*Sassafras albidum*], and mockernut hickory [*Carya tomentosa*]) were present in the large tree stratum but not in the small tree stratum. Interestingly, all of the more important large tree species displayed generally similar levels of abundance in the small tree stratum. Red spruce was the most consistently present of the small tree species and was recorded at twelve of the fifteen localities (20 stands); except for hemlock (11 stands) and yellow birch (14 stands), all other taxa occurred at fewer than ten localities. As was the case for large trees, Fraser fir was found only at Mount Rogers, where it was the most important species (Table 6).

TABLE 5. Composition of the small tree stratum (stems 2.5-9.9 cm DBH) for all 24 stands.

Species	Number stands present	Basal area (m ² /ha)	Relative basal area (%)	Density (N/ha)	Relative density (%)	Importance value
<i>Picea rubens</i>	20	0.39	29.1	141	26.7	27.9
<i>Abies fraseri</i>	5	0.26	19.4	155	29.3	24.4
<i>Tsuga canadensis</i>	11	0.15	11.2	48	9.1	10.2
<i>Betula lutea</i>	14	0.15	11.2	42	7.9	9.6
<i>Ilex ambigua</i>	6	0.06	4.5	33	6.2	5.4
<i>Hamamelis virginiana</i>	6	0.05	3.7	26	4.9	4.3
<i>Fagus grandifolia</i>	5	0.04	3.0	18	3.4	3.2
<i>Acer rubrum</i>	9	0.05	3.7	14	2.6	3.2
<i>Amelanchier arborea</i>	7	0.05	3.7	13	2.5	3.1
<i>Betula lenta</i>	8	0.05	3.7	12	2.3	3.0
<i>Sorbus americana</i>	2	0.04	3.0	6	1.1	2.0
<i>Acer pensylvanicum</i>	6	0.01	0.8	8	1.5	1.2
Other species ¹	1-3	0.04	3.0	13	2.5	2.8
Total		1.34	100.0	529	100.0	100.3

¹Includes *Acer spicatum* (3 stands), *Crataegus* sp. (3), *Magnolia acuminata* (3), *Acer saccharum* (1), *Alnus serrulata* (1), *Fraxinus pennsylvanica* (1), *Liriodendron tulipifera* (1), *Nyssa sylvatica* (1), *Quercus prinus* (1), and *Q. rubra* (1)

TABLE 6. Average importance values for species represented in the small tree stratum (stems 2.5-9.9 cm DBH) of each red spruce community subtype.

Species	Red Spruce Community Subtype		
	Fraser fir-Spruce ¹ (n = 5)	Hemlock-Spruce ("Bog") ² (n = 4)	Spruce-dominated ³ (n = 15)
<i>Picea rubens</i>	13.6	5.0	35.8
<i>Abies fraseri</i>	71.7	-	-
<i>Tsuga canadensis</i>	-	44.1	10.5
<i>Betula lutea</i>	5.5	20.3	6.9
<i>Ilex ambigua</i>	-	8.2	9.3
<i>Hamamelis virginiana</i>	-	11.4	4.5
<i>Fagus grandifolia</i>	-	0.5	5.7
<i>Acer rubrum</i>	-	0.4	6.4
<i>Amelanchier arborea</i>	-	3.4	7.2
<i>Betula lenta</i>	-	2.4	5.4
<i>Sorbus americana</i>	9.1	-	-
<i>Acer pensylvanicum</i>	-	1.9	1.8
Other species	-	2.4	6.6
Total	99.9	100.0	100.1

¹All stands located on Mount Rogers

²One stand at SNP; three stands in Giles County

³All other stands

TABLE 7. Soil chemical and physical characteristics for 24 spruce stands sampled in western Virginia (N = 96 for all parameters except sand, silt, and clay separates, where N = 24).

Parameter	Range	Mean \pm SD
Gravel (%)	0-51	16 \pm 15
Sand (%)	27-83	50 \pm 15
Silt (%)	7-51	28 \pm 10
Clay (%)	10-46	22 \pm 10
Organic matter (%)	13-67	40 \pm 39
Soil moisture (% dry wt.)	37-307	144 \pm 78
Calcium (ppm)	54-471	160 \pm 196
Potassium (ppm)	17-89	40 \pm 39
Magnesium (ppm)	10-57	24 \pm 20
Phosphorus (ppm)	4-35	16 \pm 20
Zinc (ppm)	2.5-6.1	4.4 \pm 2.9
Nitrogen (ppm)	3-32	13 \pm 20
Soluble salts (ppm)	42-1011	492 \pm 637
pH	2.9-4.4	3.4 \pm 1.0

In general, soils on which red spruce stands are found in western Virginia are sandy loams, although several other textural classes were represented (Table 7). In comparison to mid-Appalachian hardwood forests we have studied (Stephenson and Adams 1989, unpublished data), the soils of these forests are more strongly acidic and usually have higher levels of organic matter and ambient soil moisture. Otherwise, both forest types are generally characterized by low levels of most soil nutrients.

In summary, the high elevation coniferous forests that occur in the mountains of central and southwestern Virginia constitute a distinctive community type that has a rather limited distribution. This community type is characterized by the presence of red spruce in the large tree stratum, with hemlock and yellow birch as the most consistently important associated species. In fact, hemlock is sometimes the leading dominant on the most mesic (i.e., bog) sites. Fraser fir is present only at Mount Rogers, where it is the overwhelming dominant in stands located at the highest elevations.

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A Comparison of Piedmont and Coastal Plain Upland Hardwood Forests in Virginia

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ABSTRACT

Both the Piedmont and Coastal Plain of Virginia have traditionally been treated as part of the Oak-(Hickory)-Pine Forest Region. To assess the similarity of hardwood forests of these two physiographic provinces, a detrended correspondence analysis ordination (using DECORANA software) was constructed using 51 Piedmont and 22 central Coastal Plain upland hardwood forest stands. *Quercus alba* was a usual dominant in both physiographic provinces; its Importance Value (IV) exceeded 10% in 88% of the stands. On the basis of other important species, however, the stands fell into three distinct groups: (a) 15 northern Piedmont stands on Triassic substrates, with *Carya* spp. IV > 18% and little *Q. prinus* or *Q. coccinea*; (b) non-Triassic Piedmont stands from the southern, central, and northern Piedmont, with one or both of *Q. prinus* and *Q. coccinea* with IV > 10%; and (c) 22 Coastal Plain stands usually with high IV of *Fagus grandifolia* or *Q. falcata*. The Coastal Plain forests had more in common with the *Fagus*-rich Southern Mixed Hardwood Forest of the southeastern Coastal Plain than with the much nearer forests of the Virginia Piedmont.

INTRODUCTION

Both the Piedmont and central Coastal Plain of Virginia have traditionally been treated as part of the Oak-(Hickory)-Pine Forest Region, with oak-hickory forest regarded as the potential upland climax which would develop with the demise of the successional shortleaf (*Pinus echinata*), Virginia (*P. virginiana*), and loblolly (*P. taeda*) pines (Braun, 1950; Oosting, 1956; Kuchler, 1964). Braun's (1950) grouping of these two physiographic provinces into the same forest region was not based on much quantitative data, but largely on visual observation of the vegetation. The first modern quantitative vegetational study of the upland oak-hickory forests of the Piedmont was carried out by Gemborys (1974) in Prince Edward Co., Virginia (Fig. 1), and this inspired a similar study of upland hardwood forest stands in six central Coastal Plain counties (Fig. 1) by DeWitt and Ware (1979).

Though the differences in sampling methods and data analysis made direct quantitative comparison between the two studies impractical, DeWitt and Ware (1979) did compare a list of the most important species in the central Coastal Plain with a list of the most important species found in the upland stands among those in Gemborys' (1974) Piedmont study. This comparison revealed that white oak (*Quercus alba*) was the most important species in both areas, but the abundant Piedmont oak species chestnut (*Q. prinus*), scarlet (*Q. coccinea*), and northern red oak (*Q. rubra*) were unimportant in the Coastal Plain. On the other hand, beech (*Fagus grandifolia*) had high importance in the Coastal Plain but was rare in the Piedmont. DeWitt and Ware (1979) thus concluded that their Coastal Plain forest stands had

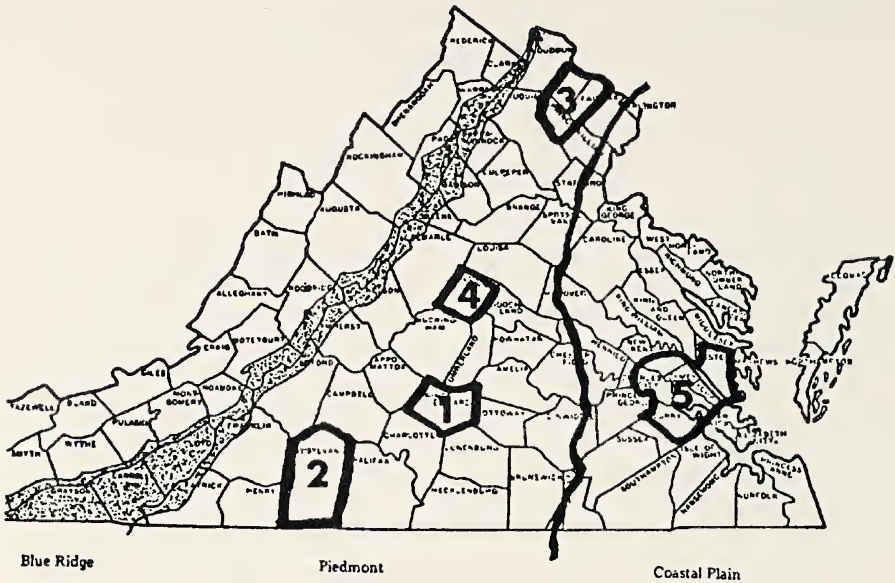


FIGURE 1. Location of the study areas in the Piedmont and Coastal Plain of Virginia. 1 = Gemborys (1974); 2 = Clark and Ware (1980); 3 = Farrell and Ware (1991); 4 = Diggs and Hall (1981); and 5 = DeWitt and Ware (1979) and Monette and Ware (1983). Base map modified from Harvill (1970).

a closer relationship to the beech-rich stands of the Coastal Plain to the south (Quarterman and Keever, 1962) than to the oak-hickory forests of the Piedmont. Despite these conclusions and a later reiteration (Monette and Ware, 1983) of the similarity of Virginia Coastal Plain upland forests to those farther south, most workers have continued to treat both the Piedmont and Coastal Plain of Virginia as part of the same forest region--the Oak-(Hickory)-Pine Region (Vankat, 1979; Greller, 1988).

In the last decade three additional studies (Fig. 1) of upland forest vegetation have been carried out in the Piedmont of Virginia using the same combined Bitterlich-circular quadrat method (Levy and Walker, 1971) employed by DeWitt and Ware, (1979). This similarity of method allows direct quantitative comparisons of DeWitt and Ware's (1979) Coastal Plain data with that from the more recent Piedmont studies. The present paper makes that comparison of 22 central Coastal Plain forests with those from the Piedmont. The Piedmont forests include 22 upland hardwood stands in the southern Virginia Piedmont (Clark and Ware, 1980), four upland hardwood stands in Fluvanna Co. in the central Piedmont (Diggs and Hall, 1981), and 25 upland hardwood stands in the Piedmont portions of Fairfax, Loudoun, and Prince William counties in northern Virginia (Farrell and Ware, 1991).

METHODS

In all four studies (DeWitt and Ware, 1979; Clark and Ware, 1980, Diggs and Hall, 1981, and Farrell and Ware, 1991) stands were chosen which were

predominantly hardwood, without saw-cut stumps or other obvious signs of recent ($> 20\text{--}30$ yr) disturbance, and were large enough to allow at least three combined Bitterlich-circular quadrat sample points (Levy and Walker, 1971). At each point basal area of each species was measured by the Bitterlich method using either a Bitterlich stick or a Spiegel Relaskop (sighting prism). Density of each species was measured by counting all tree stems ≥ 10.16 cm (4 in) in diameter at breast height (dbh). In each stand relative basal area and relative density of trees were calculated for each species, and then the relative values were averaged to yield importance value (IV; base of 100) for that species in that stand. Both the statistical tests (Sokal and Rohlf, 1981) of the tabular data and the detrended correspondence analysis (DCA) ordinations (using DECORANA software; Hill and Gaugh, 1980) were based on IV's. Because of the great difficulty of reliably distinguishing the hickories *Carya glabra* and *C. ovalis* in the field in summer when nuts are not available (Johnson and Ware, 1982), these two taxa were combined in this analysis, regardless of which name was applied by the original workers. There were 22 southern Piedmont stands, 25 northern Piedmont stands, and four central Piedmont stands, for a total of 51 Piedmont stands, and 22 Coastal Plain stands, for a grand total of 73 stands.

RESULTS

Because the northern and southern Piedmont studies are farther from one another geographically than either is from the central Coastal Plain, it was necessary first to ask whether these two Piedmont areas were sufficiently similar that they might be combined for comparison with the Coastal Plain. Table 1 compares the frequency of an IV $> 10\%$ and the presence for each major species in the northern versus the southern Piedmont. White oak was the overwhelming dominant in both areas. The remaining species in the upper part of Table 1 were more important in the south, and those in the lower half of the table (*Q. velutina* downward) were more important in the north. Based on this comparison, the southern and northern Piedmont appear to be quite different ($P < 0.05$, G test for goodness of fit). However, fifteen of the stands in northern Virginia are on Triassic substrates of the Leesburg Basin, while the other ten stands, like those of the rest of the Piedmont, are on Paleozoic or pre-Cambrian substrates (Fig. 2). A comparison of the composition of the Triassic and non-Triassic northern Virginia stands (Table 2; significantly different at the $P < 0.05$ level, G test for goodness of fit) revealed that the species which were more abundant in the north were generally those species which reached high importance in the Triassic, and those species more important in the south were mostly ones which were less abundant on Triassic substrates. The exceptions were sourwood (*Oxydendron arboreum*), which does not range into the northern Piedmont study area (Harvill et al., 1986), blackgum (*Nyssa sylvatica*), which was more important in the north but mostly on non-Triassic substrates there, and northern red oak, which was more important in the north but apparently not substrate specific. The ten non-Triassic stands in the northern Piedmont (Table 2) had a fairly similar composition (NS, G test for goodness of fit) to the southern Piedmont (Table 1) and central Piedmont (Fluvanna Co.) stands (Diggs and Hall, 1981). Therefore, these ten northern Virginia stands and the four central Virginia stands were combined with the 22 southern Virginia stands to produce a 37-stand

TABLE 1. Presence and importance of major overstory species in upland hardwood forests of the southern and northern Virginia Piedmont. All hardwood species are listed which had an IV > 10 in at least one stand in either area, or were present in at least half the stands in either area.

	Southern (n = 22)		Northern (n = 25)	
	With IV > 10 % (n)	Present % (n)	With IV > 10 % (n)	Present % (n)
<i>Quercus alba</i>	86.4(19)	100.0 (22)	80.0 (20)	100.0 (25)
<i>Q. prinus</i>	54.5(12)	72.7 (16)	16.0 (4)	24.0 (6)
<i>Q. coccinea</i>	45.5(10)	95.5 (21)	20.0 (5)	52.0 (13)
<i>Liriodendron tulipifera</i>	31.8 (7)	59.1 (13)	4.0 (1)	52.0 (13)
<i>Acer rubrum</i>	27.3 (6)	86.4 (19)	16.0 (4)	44.0 (11)
<i>Oxydendron arboreum</i>	9.1 (2)	81.1 (18)	-- (0)	-- (0)
<i>Q. falcata</i>	9.1 (2)	59.1 (13)	-- (0)	36.0 (9)
<i>Liquidambar styraciflua</i>	4.5 (1)	13.6 (3)	-- (0)	-- (0)
<i>Q. stellata</i>	-- (0)	50.0 (11)	-- (0)	20.0 (5)
<i>Q. velutina</i>	18.2 (4)	86.4 (19)	48.0 (12)	96.0 (24)
<i>Carya tomentosa</i>	4.5 (1)	68.2 (15)	40.0 (10)	72.0 (18)
<i>C. glabra/ovalis</i>	4.5 (1)	68.2 (15)	36.0 (9)	84.0 (21)
<i>Nyssa sylvatica</i>	9.1 (2)	95.5 (21)	28.0 (7)	64.0 (16)
<i>Q. rubra</i>	-- (0)	4.5 (1)	24.0 (6)	76.0 (18)
<i>Fraxinus americana</i>	-- (0)	9.1 (2)	16.0 (4)	44.0 (11)
<i>Ulmus rubra</i>	-- (0)	-- (0)	8.0 (2)	40.0 (10)

Piedmont composite, and then compared with the 22 Coastal Plain stands (Table 3). The two groups are significantly different at the $P < 0.01$ level (G test for goodness of fit).

Excluding white oak, the species in Table 3 can be placed into three groups: six species noticeably more important in the Piedmont; five species more or less equally important in both Coastal Plain and Piedmont; and six species more important in the Coastal Plain. In the first group, chestnut oak and scarlet oak were not only much less likely to have high IV in the Coastal Plain, but they were also less likely to be present, while in the next three species the difference in structural importance was more pronounced than the difference in presence. In the second group, both *Carya glabra/ovalis* and *C. tomentosa* as well as the Table 2 species American ash (*Fraxinus americana*) and slippery elm (*Ulmus rubra*) would seem to be more important in the Piedmont if Triassic sites had been included, but were actually no more important in the Piedmont than in the Coastal Plain when only the far more extensive Paleozoic and pre-Cambrian Piedmont sites were considered. In the third group, the greater importance of beech and southern red oak (*Quercus falcata*) is based on both IV and presence, while that of holly (*Ilex opaca*), basket oak (*Q. michauxii*) and sand hickory (*C. pallida*) is based on presence only. The latter two species do not range as far west into the Piedmont as the sampled sites are located (Harvill et al., 1986), so those species would not be expected in the sampled stands from that physiographic province.

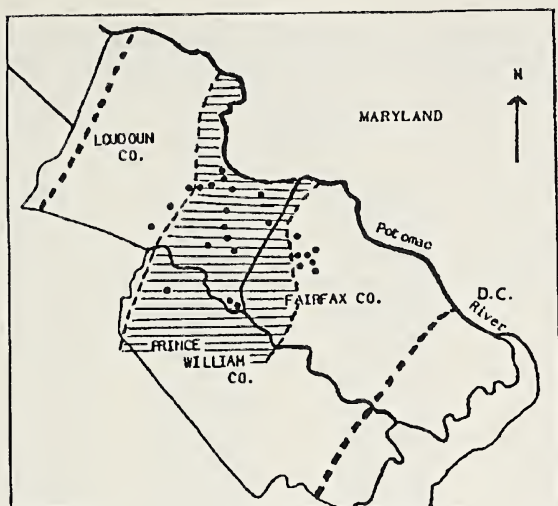


FIGURE 2. Location of Triassic and non-Triassic sites in the northern Piedmont area studied by Farrell and Ware (1991). The Triassic belt (Leesburg Basin) lies in western Fairfax and eastern Loudoun counties, separated by dashed lines from the non-Triassic areas to the east and west of it.

These tabular comparisons were all based on arranging stands by geographic, physiographic, or geological categories, a kind of direct environmental analysis, as opposed to an *indirect* environmental or vegetational arrangement of stands, such as in a detrended correspondence analysis (DCA) ordination. When all 73 stands were plotted on the first two axes of such an ordination, they fell into three identifiable groups based on their geological and physiographic origins (Fig. 3). The group of 17 stands on the lower right of the ordination is designated TR because 14 of them are in the Triassic basin of northern Virginia. The remaining three are from non-Triassic northern Piedmont sites (2 stands) or Fluvanna County (one stand). The group of 21 stands in the upper center of Fig. 3 are designated CP because all except two of them are Coastal Plain stands. The two added stands are one southern Piedmont and one central Piedmont stand. Each of these has southern red oak IV > 10, a species which was often important in Coastal Plain stands. The third group of 34 stands, consisting of 21 southern Piedmont stands, 11 northern Piedmont stands, two central Piedmont stands, and two Coastal Plain stands, constitutes a representative sample of what present day upland hardwood forests of the non-Triassic Piedmont are like, and are designated PD. The two Coastal Plain stands in this group had red maple (*Acer rubrum*) IV > 10, like many Piedmont but unlike most other Coastal Plain stands, and did not have much beech or southern red oak. In a second DCA ordination in which the 17 TR stands were omitted and only the typical Piedmont and the Coastal Plain stands were included (Fig. 4), the stands from the two different physiographic provinces again fell in different portions of the ordination, and this time the two Coastal Plain stands mentioned above did not fall with the PD stands, but lie between them and the CP stands (Fig. 4). Thus, indirect (vegetational) analysis and direct physiographic and geological analyses produced very similar groupings of stands, with only two stands falling in the wrong physiographic province on the second ordination (Fig. 4).

TABLE 2. Comparison of presence and importance of major overstory species on Triassic and non-Triassic substrates in northern Virginia. All hardwood species which had an IV 10 on either substrate are included.

	Triassic (n = 15)		Non-Triassic (n = 10)	
	With IV > 10 % (n)	Present % (n)	With IV > 10 % (n)	Present % (n)
<i>Quercus alba</i>	86.7(13)	100.0 (15)	70.0 (7)	100.0 (10)
<i>Nyssa sylvatica</i>	6.7 (1)	46.7 (7)	60.0 (6)	90.0 (9)
<i>Q. prinus</i>	-- (0)	6.7 (1)	40.0 (4)	50.0 (5)
<i>Q. coccinea</i>	-- (0)	53.3 (8)	40.0 (4)	50.0 (5)
<i>Acer rubrum</i>	6.7 (1)	26.7 (4)	30.0 (3)	70.0 (7)
<i>Liriodendron tulipifera</i>	-- (0)	20.0 (3)	10.0 (1)	100.0 (10)
<i>Q. rubra</i>	26.7 (4)	80.0 (12)	20.0 (2)	70.0 (7)
<i>Q. velutina</i>	53.3 (8)	93.3 (14)	40.0 (4)	100.0 (10)
<i>Carya glabra lovalis</i>	46.7 (7)	93.3 (14)	20.0 (2)	70.0 (7)
<i>C. tomentosa</i>	60.0 (9)	93.3 (14)	10.0 (1)	40.0 (4)
<i>Fraxinus americana</i>	26.7 (4)	66.7 (12)	-- (0)	10.0 (1)
<i>Ulmus rubra</i>	13.2 (2)	60.0 (9)	-- (0)	10.0 (1)

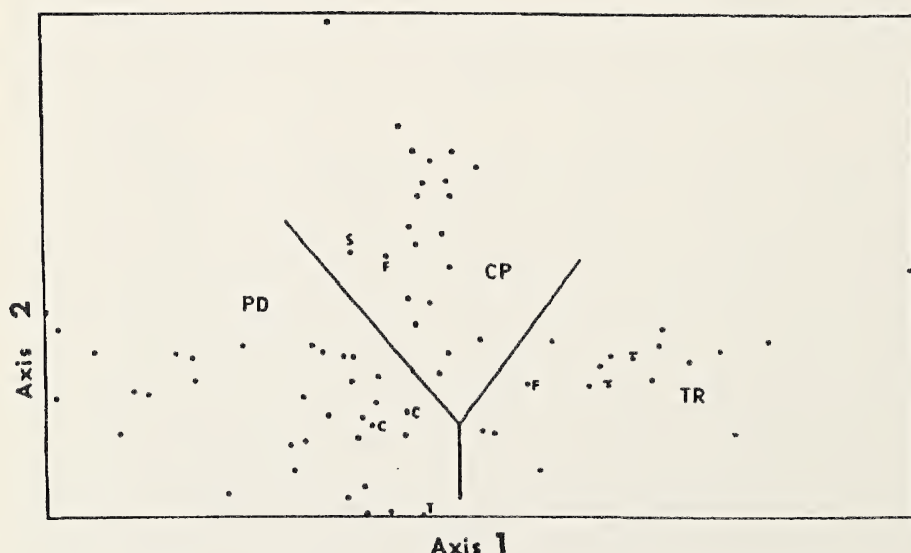


FIGURE 3. DCA ordination of 73 Piedmont and Coastal Plain stands. Group TR contains 14 northern Triassic stands, along with one central Virginia (F) stand and two non-Triassic northern Virginia stands (bar above the dot). The upper center group CP contains 19 Coastal Plain stands and one southern (S) and one central (F) Piedmont stand (both with high *Quercus falcata* IV). The remaining group (PD) consists of 31 non-Triassic Piedmont stands and three *Acer rubrum*-rich stands from the Triassic (T) or Coastal Plain (C). Only four stands fail to group with others from their physiographic province.

TABLE 3. Comparison of importance and presence of major overstory species of the central Coastal Plain and the Piedmont (non-Triassic). All species with IV > 10 in at least one stand are included.

	Piedmont (n = 36)		Coastal Plain (n = 22)	
	With IV > 10 % (n)	Present % (n)	With IV > 10 % (n)	Present % (n)
<i>Quercus alba</i>	83.3(30)	100.0 (36)	90.9 (20)	100.0 (22)
<i>Q. prinus</i>	50.0(18)	63.9 (23)	-- (0)	4.5 (1)
<i>Q. coccinea</i>	41.6(15)	75.0 (27)	-- (0)	31.8 (7)
<i>Q. velutina</i>	27.8(10)	91.6 (33)	4.5 (1)	68.1 (15)
<i>Acer rubrum</i>	27.8(10)	83.3 (30)	9.1 (2)	81.8 (18)
<i>Nyssa sylvatica</i>	22.2 (8)	91.6 (33)	-- (0)	68.1 (15)
<i>Oxydendron arboreum</i>	5.5 (2)	50.0 (18)	-- (0)	31.8 (7)
<i>Q. stellata</i>	2.7 (1)	50.0 (18)	-- (0)	36.3 (8)
<i>Carya glabra/ovalis</i>	8.3 (3)	69.4 (25)	-- (0)	68.1 (15)
<i>C. tomentosa</i>	5.5 (2)	63.9 (23)	4.5 (1)	72.7 (16)
<i>Q. rubra</i>	5.5 (2)	27.7 (10)	9.0 (2)	68.1 (15)
<i>Liriodendron tulipifera</i>	22.2 (8)	66.7 (24)	22.7 (5)	86.3 (19)
<i>Liquidambar styraciflua</i>	2.7 (1)	13.8 (5)	4.5 (1)	86.3 (19)
<i>Q. falcata</i>	8.3 (3)	55.4 (20)	27.3 (6)	90.9 (20)
<i>Fagus grandifolia</i>	-- (0)	2.7 (1)	54.4 (12)	81.8 (18)
<i>Ilex opaca</i>	-- (0)	2.7 (1)	4.5 (1)	86.3 (19)
<i>Q. michauxii</i>	-- (0)	-- (0)	4.5 (1)	36.6 (8)
<i>C. pallida</i>	-- (0)	-- (0)	4.5 (1)	22.7 (5)

DISCUSSION

In the tabular comparison of groups of stands it is important to remember that all stands were second growth, and that all data presented here are based on overstory trees (≥ 10.16 cm dbh). Some of the differences between stands may be products of differential disturbance histories, and some differences may be because species were present in the understory but not picked up in the overstory sample. Red maple and blackgum are quite commonly present in upland forests of the Coastal Plain, but usually as understory trees, so that they are often too small to be recorded in sampling data based on larger trees. (However, both regularly reach the canopy in bottomland forests of the Coastal Plain; see Glascock and Ware [1979]). Sourwood is also a common understory species in the Coastal Plain, so it likewise may have been present in the understory in many of the sampled stands but not recorded in the overstory. In the Coastal Plain both red maple and sourwood may experience an increase in growth after selective timbering has opened up the canopy, and under those conditions may reach a dbh of > 10 cm. If this is also true in the Piedmont, the high importance of these two species in upland stands there might be a product of past selective timbering which took place so long ago that it is no longer detectible by saw-cut stumps or other signs of such disturbance. However, why such a result would have occurred more often in the southern, central, and northern Piedmont and in Gemborys' (1974) study area than

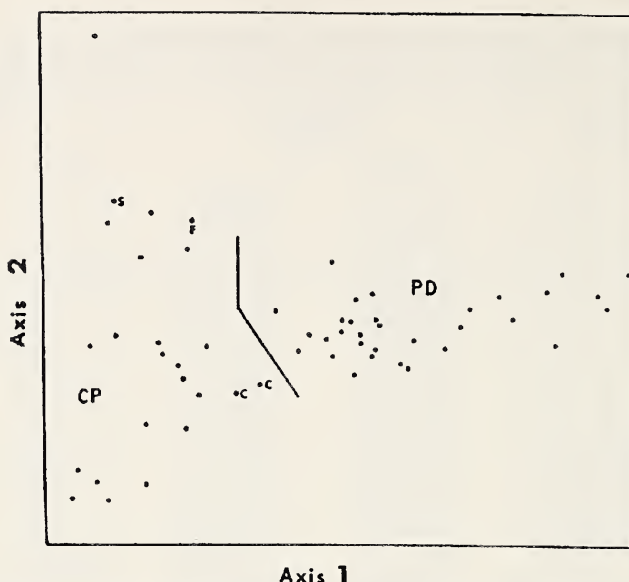


FIGURE 4. DCA ordination of PD and CP stands from Figure 3. The two (C) stands from Figure 3 now fall closer to the other Coastal Plain (CP) stands than to the PD stands, while F and S from the Piedmont again fall with *Quercus falcata*-rich Coastal Plain stands. Stands in the lower left have high IV of *Fagus grandifolia*.

in the Coastal Plain is unclear. It may well be that in general blackgum, red maple, and sourwood are simply more successful in the Piedmont than in the Coastal Plain. Such greater success in the Piedmont seems to be the case with black oak, often present in Coastal Plain stands but usually represented there by relatively few individuals.

The apparent greater importance of the pignut hickory complex (*Carya glabra/ovalis*) in the Piedmont was because of two northern Virginia stands which (according to county soil maps) are on non-Triassic soils but which had the higher soil Ca, Mg, and pH which usually characterizes Triassic soils (Farrell and Ware 1991). On the ordination these two stands fell with the Triassic sites in the group TR, and thus are anomalous as members of the non-Triassic grouping in Table 2. If they were excluded from the comparison, the pignut hickory complex would be of similar importance in both the PD and CP groupings.

Tuliptree (*Liriodendron tulipifera*) is extremely abundant in the Coastal Plain, perhaps second only to loblolly pine in abundance. Its lower IV in the Coastal Plain (Table 3) is related to stand selection criteria used in this study. Stands with abundant tuliptree usually have either much loblolly pine (younger stands) or relatively little white oak (older stands), both of which are signs of past selective cutting, and such stands were excluded. In the Piedmont the proportion of stands with tuliptree present was lower than in the Coastal Plain, but the proportion of stands with abundant tuliptree which were without clear evidence of past selective timbering (and thus suitable for sampling) was about the same.

The low importance of northern red oak in non-Triassic sites in the three recent Piedmont studies is in contrast to the high importance of that oak in Gemborys' (1974) study, a point first noted by Clark and Ware (1980). The three more recent

Piedmont studies have all reported the presence of both scarlet oak and northern red oak (with the former not infrequently having a high IV). However, Gemborys (1974) reported only the presence of northern red oak; therefore it seems probable that the name *Quercus rubra* as used by Gemborys (1974) is inclusive, and encompasses individual trees which other workers may have separated out as scarlet oak.

The contrast in the importance of southern red oak in the Piedmont and Coastal Plain seems clear based on these data. However, it should be noted that in Gemborys' (1974) study, southern red oak had a relative importance among potential canopy species greater than 10% in six of 24 upland stands (25%), and it was present in either overstory or understory in 20 of the 24 stands (83.3%). These values are quite comparable in importance to what DeWitt and Ware (1979) found in the Coastal Plain.

While one should not forget the caveat noted above about interpreting comparisons of hardwood stands which may have different disturbance histories, the fact is that the indirect gradient analysis (DCA ordination) produced a grouping of stands which deviates only in minor ways from the *a priori* grouping by physiographic and geologic categories. Thus, the recent data on Piedmont hardwood forests support the notion advanced by DeWitt and Ware (1979) that the Piedmont and the central Coastal Plain of Virginia are different vegetationally. Despite the masking dominance of white oak in many stands, the difference manifests itself largely in the higher importance of chestnut, scarlet, and black oak in the Piedmont versus the higher importance of beech and southern red oak in the central Coastal Plain. To treat these as parts of a single forest region, especially of a region for which beech is not listed as one of the common canopy dominants, is not consistent with the available quantitative data.

All of the study sites discussed in this paper are well within the Piedmont or well within the Coastal Plain, so it cannot be discerned from the data presented here whether the usual boundary (the Fall Line) between these two physiographic provinces is also a vegetational boundary. The vegetational boundary is likely to be a transition zone much less discrete than the physiographic boundary, and may well be west of the Fall Line. A study of the shrub/herb layers in 30 hardwood forests along a 116 km east-west transect across the Fall Line through New Kent, Hanover, and Louisa counties VA (Binns 1980) revealed no sharp vegetational changes, and my comparison of that study with shrub data from Monette and Ware's (1983 and unpublished) central Coastal Plain study revealed no significant differences in shrub layer composition between the Piedmont and Coastal Plain stands. Further work is needed to determine the location and width of the boundary area between the two vegetational areas, and whether the shrub and herb layers respond in the same way that the overstory layer does. Given the putative southern relationship of the central Coastal Plain studies, more work also needs to be done in the northern Coastal Plain of Virginia to determine whether that region is more like the central Coastal Plain to the south or the Piedmont to the west.

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The Vegetation of the Great Dismal Swamp: a Review and an Overview

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ABSTRACT

The vegetation of the Great Dismal Swamp is recovering from 200 years of anthropogenic disturbance which included numerous fires, repeated logging operations and primarily during this century, the construction of over 100 miles of drainage ditches, many with parallel roads. Most plant communities consist of second- or third-growth forest and dense shrub-dominated communities that represent a variety of seral stages. The storied cypress-tupelo gum swamps are represented by remnants and the extensive Atlantic White Cedar stands have been decimated. The once common "lights", composed of reeds and aquatic grasses, have succeeded to red maple dominated communities. In fact, red maple dominates or is an important component of most community types which have been delimited.

THE VEGETATION OF THE GREAT DISMAL SWAMP

The Great Dismal Swamp of Virginia and North Carolina, which covers about 104,000 ha, has been greatly disturbed by fire and 200 years of logging and draining (Meanley, 1968; Dean, 1969). Most of its vegetation consists of second growth communities in various seral stages (Levy and Walker, 1979).

The Virginia portion of the Dismal Swamp includes the eastern part of the City of Suffolk and the western part of the City of Chesapeake. In North Carolina it constitutes parts of Currituck, Camden, Perquimans, Gates and Pasquotank counties.

The southeastern coastal plain of the United States harbors a great diversity of communities. Since the region's climate is "relatively uniform" it is reasonable to attribute its vegetative mosaic to individual species' responses to edaphic and physiographic variation (Wells, 1942). The vegetation of the Great Dismal Swamp is influenced by the geological processes which formed its western boundary (the Suffolk Scarp), the five lagoonal strata of Pleistocene Age that underlie the surface peat deposits, and below them the Yorktown Formation (Oaks and Coch, 1963, Oaks et al., 1974). The Yorktown Formation, which in this area is mainly compact, impermeable clay, slopes eastward at about 0.25 m/km. It forms a barrier which prevents downward groundwater percolation and thereby provides the major hydrological impedance that has delimited the area's ecological diversity.

Palynological studies of Dismal Swamp peat (Cocke et al., 1934; Whitehead, 1972; Whitehead and Oaks, 1979) have provided insight into the vegetational history of this area. Whitehead and Oaks (1979) have concluded that the surface upon which the Dismal Swamp formed dates from the last (Sangamon) interglacial (<80,000 B.P.). Indications of a dendritic drainage system in the surface of the sediment beneath the peat, peat radio-carbon data, and pollen analysis provided the basis for their estimate of 11,000-12,000 years B.P. for the swamp's initiation.

It appears that forest vegetation was initially confined to the margins of the Dismal Swamp basin or to mesic islands within it. The major portion of the basin likely had aquatic and semiaquatic communities associated with meandering creek margins, sloughs and ponds. Peat seems to have first begun to form in the eastern portion of the basin within ponded areas. Due to its high water retaining capacity the peat created the conditions for its subsequent accumulation and expansion. Ultimately much of the basin was covered by a peat blanket ranging from a maximum reported depth of 5.5 m east and northeast of Lake Drummond (Osbon, 1919) to none at other sites (Oaks and Whitehead, 1979).

In summary, Oaks and Whitehead (1979) concluded that since the swamp's inception the region has undergone an overall warming trend. They identified four pollen assemblages: 1) pine-spruce, 2) beech-hemlock-birch; 3) oak-hickory; and 4) cypress-gum. The cypress-gum assemblage was dated from 3,500 B.P. to the present. This last assemblage was found to consist of the pollen of many species presently found in the Great Dismal Swamp.

Historical descriptions of the Dismal Swamp's vegetation began with the observations of William Byrd II (1958), who in 1728 helped supervise the Virginia--North Carolina boundary line survey. He described areas on the eastern edge as having a dense undergrowth, including reeds 10-12 ft. high, intertwined with briars. Scattered throughout this portion were a few cypresses and white cedars. He wrote, "... the ground was moist and trembling under our feet like a quagmire in-so-much that it was an easy matter to run a ten-foot pole up to the head in it without exerting any uncommon strength to do it." Byrd reported that the surveyors encountered large, blown down cypresses. As they further penetrated the swamp they found an increase in white cedars. They continued making good progress until on the third day when about five miles into the swamp they encountered an "... impenetrable cedar thicket." The following day they traversed "... a cedar bog where the trees were smaller and grew more into a thicket." On the ninth day having run out of supplies the surveyors "... marched from morning till night, and completed ..." the remaining four miles through a cedar swamp.

In 1763 George Washington joined eleven other distinguished Virginians in forming a company which eventually became known as the Dismal Swamp Land Company. A scattering of comments through his letters and diaries provides some sparse descriptions of the swamp's vegetation. Cypress, juniper and growths of cane are noted.

From May 25th to the 28th 1763, Washington and some companions rode around the perimeter of the Swamp. At this time he noted relatively dry conditions in places. Near Cypress Swamp, on its western edge, they penetrated more than a half mile and noted, "... Pine and Galeberry bushes, the soil being much intermixed with sand but afterwards it grew blacker and richer with many young Reeds and few pines, and this it may be observed here is the nature of the Swamp in general." Continuing around the Swamp and through the southern portion they passed through "Newland", an area with little timber "... but very full of Reeds ..." (Fitzpatrick, 1925).

In 1795 J.F.D. Smyth's travels and adventures led him to hide from rebel militia in the Great Dismal Swamp (Smyth, 1968). His account entitled, "A Tour in the United States of America; [etc.]" includes observations on the Dismal. He

describes "... innumerable quantities of large straight lofty cypress trees." Their knees are described as being from 3 to 15 inches in height, suggesting that mean water levels then were much as they are today (Kernell and Levy, 1990). He especially mentions ridges of higher ground that had been accidentally set on fire in very dry summers producing "... dreadful conflagrations ... burning into the earth for vast depth. . .", these places soon becoming small lakes. He specifically mentions a particular fire which produced a lake, "... a mile and a half by three long and up to 12 feet deep." He wrote, "It is imagined that the great lake in the center [Lake Drummond] was formed by some dreadful conflagration far beyond human memory; as burnt wood is frequently found . . . throughout."

Stewart (1981) provides various descriptions of the shingle and lumber industries in the Great Dismal. From his gleanings of the various records of economic activity some ideas of the dominant vegetation of the swamp from the 1760's through more recent times can be deduced and the factors which influenced this vegetation inferred.

It seems apparent, as J.F.D. Smyth originally summarized in 1775, that drought, fire and storms have played a significant role in effecting the Swamp's vegetative characteristics. Certainly William Byrd II's earlier descriptions of the hardships involved in setting the dividing line supports the on-going influences of both blow down and fire, as does Washington's reports of extensive areas with little timber, "Galeberry bushes" and reeds.

Fires are reported by Stewart (1981) as having adverse economic effects in various portions of the Dismal Swamp in the first two decades of the nineteenth century and in 1836. In 1913 fires and a hurricane are noted as "... reducing the enthusiasm" for the lumber business in the Dismal Swamp by the steel men who ran the Norfolk Southern Rail Road.

Dean (1969) presents historical descriptions of some interest and some details on the history of 20th century fires and fire suppression efforts. Worthy of note are the fires of the 1920's, 1930 and 1931. From 1932 to 1941 fires were allowed to burn without interference. Additional important fires are reported for 1942 and 1952. Currently, although fire suppression is a priority, parts of the swamp burn almost every year. In times of drought, ground fires still become established in the peat and despite great human effort, natural precipitation often plays the decisive role in suppressing them.

The historical impact of fire has likely been exacerbated by lumbering and ditch building activities. Prior to the 1760's most lumbering activities appear to have been small scale, individual efforts on the edges of the swamp. However, beginning in the 1760's logging efforts became more organized and roads and ditches were constructed to facilitate access and removal of forest products (Stewart, 1981).

Since the first five mile ditch was constructed at some time prior to 1772 (Berkeley and Berkeley, 1976), approximately 120 miles of ditches have been dug. These ditches have almost obliterated all the natural streams within the Great Dismal (U.S. Dept. of the Interior, 1979). Although some ditches date from the 18th and 19th centuries, the majority of the ditches were constructed during the 20th century. The impact of these ditches has been to accelerate the successional process, by drying the peat and increasing the risk of fire.

Most descriptions of the Dismal Swamp's vegetation are floristic listings and qualitative descriptions of community-types. Kearney (1901) distinguished two hydrophilic forest formations: Dark Swamp and Light Swamp. The former was described as dense deciduous virgin forest and the latter as almost pure stands of Atlantic white cedar (*Chamaecyparis thyoides*). Meanley (1968) reported the following "major" plant communities: "Cypress-Tupelo Gum, Swamp Black Gum, Mixed Swamp (Red Maple -Swamp Black Gum or Tupelo Gum), Pocosin or Evergreen Shrub Bog, Atlantic White Cedar, Switch Cane, and Upland Border (oaks, ashes, elms,loblolly pine and others)." Dean (1969) identified gum swamps along natural drainage composed of "... small maples, bays, cypress ... larger ones may contain great hollow snags of cypress, gum, water oak and associated species." He also describes a pine zone of loblolly and pond pine (*P. serotina*) along ditch and canal banks; "lights" composed of reeds and water grass; and white cedar stands on acidic peat overlying a sandy subsoil.

In 1972 the first quantitative vegetative studies of the Dismal Swamp's forests were begun (Levy and Walker, 1979). Fourteen forested sites (all located in Virginia) were selected through the use of series DFU/1963 and DGF/1970 black and white aerial photographs. After extensive ground truthing and sampling of the 14 stands, they concluded that they had adequately represented the Virginia portion of the swamp. Subsequently it was learned that a cypress (*Taxodium disticum*) dominated community type had been overlooked. To date no quantitative vegetation studies have been made in the pocosin, bog or marsh communities.

Among the types included in their study, Levy and Walker (1979) concluded that the prevalent community of peat soils was dominated by red maple (*Acer rubrum*) and black gum (*Nyssa sylvatica*) with only a few additional tree species. This community appears to have been established on logged over Atlantic white cedar stands. Stewart's (1981) report of commercial shipments of cedar shingles and staves and reports of fires suggests that the extensive cedar stands noted by Byrd in 1728 were cut between 1730 and 1836. A switch to cypress logging in the 1850's is evident from commercial records. After the Civil War, new stands of cedar, likely established as a result of fires which followed the logging, are noted. The period from 1868 -1910 was a time of renewed cedar cutting.

From 1900-1910 the Richmond Cedar Works company extensively cut the eastern side of the Dismal Swamp and in the 1920's the Camp corporation started to log off the western portion including the last virgin tract in 1937 (Dean, 1979). It is likely that it was these later cedar cuttings, coupled with fire and draining caused by ditch construction, that provided the environment for the red maple - black gum community described by Levy and Walker (1979).

Levy and Walker (1979) found mixed swamps to generally occur on mineral soils. These communities have lower densities of red maple and black gum and a greater species richness than the community of peaty substrates (a mean of 8.80 tree species compared to 6.12). Ash (*Fraxinus spp.*) species had higher importance values in wetter areas, and sweet gum (*Liquidambar styraciflua*) and loblolly pine (*Pinus taeda*) grow on relatively drier sites. The latter sites usually had a low species richness (a mean of 4.0). Their study of the understory composition of these stands led Levy and Walker (1979) to conclude that the future forests would be generally more uniform and that the vegetation would be a continuum with red maple

important throughout, ash more important in wetter portions, sweet gum important in areas which are a little drier, and holly (*Ilex opaca*) and red bay (*Persea borbonia*) more important in those areas that fluctuated seasonally between wet and dry conditions.

Dabel and Day (1977) studied four forest communities in the Dismal Swamp, including three stands sampled in Levy and Walker's (1979) study. Their fourth type was a cypress dominated stand, the forest type Levy and Walker previously overlooked. This stand had an overstory which included 8 species. Cypress comprised 46.7% of the relative dominance and 18.6% of the relative density. Green ash (*F. caroliniana*) had the second highest relative density (20.5%) but the second lowest relative dominance (3.5%). Other species included red maple, black gum, water gum (*Nyssa aquatica*), sweet gum, beech (*Fagus grandifolia*) and laurel oak (*Q. laurifolia*).

Messmore (1975) utilized satellite data from Landsat I and the LARS data processing system to map the Dismal Swamp's vegetation. Unfortunately the low resolution of this system allowed only the most general delimitation of vegetation types.

Gammon and Carter (1979) produced a Great Dismal Swamp vegetative Cover Map (Carter and Gammon, 1976). Utilizing color IR photography they delimited 10 canopy classes, 3 understory classes and 3 altered vegetation classes. Of the canopy classes Pine, Atlantic white cedar and Cypress constituted individual species units. The remaining classes were delimited by two or more frequently associated species. Red maple, which occurs throughout the Swamp under all moisture conditions, dominated 1 class, co-dominated a second and was a sub-dominant in all other classes.

It was estimated by planimetry that a gum-cypress community (including water and swamp black gum) covers about 5100 ha mostly in the western portion on sites covered by standing water during the winter months. Hydric Hardwoods (red maple, swamp black gum and ash) occupy about 23,800 ha, and Mesic Hardwoods about 240 ha in areas near the Suffolk Scarp and on a series of low sandy ridges which occur across the southern portion of the Swamp (North Carolina). This latter community includes beech, various oaks, sweet gum, yellow poplar (*Liriodendron tulipifera*), pine and sourwood (*Oxydendrum arboreum*).

A pine community covers about 8,000 ha in the northern and southeastern sections. Loblolly pine tends to occur on drier sites while pond pine is more prevalent on wetter ones. A 160 ha Evergreen Shrub Bog community, composed principally of inkberry (*I. glabra*) with other *Ilex* species and bays (*Persea borbonia* and *Magnolia virginiana*), forms a matrix for scattered red maples, pond pines and Atlantic white cedars.

In the northeastern portion an Atlantic White Cedar community occurs as solid blocks of "single" age stands and as an important component of more diverse composition. However the greatest coverage of Atlantic White Cedar occurs south of Lake Drummond, with the largest stands confined to North Carolina. For the Swamp as a whole about 2800 ha are dominated by Atlantic White Cedar.

Prior to 1955 (just south of the Virginia line) a 120 ha remnant marsh community existed. Since then ditching has reduced water levels and all but about 12 ha is covered by a young red maple stand (U.S. Dept. of the Interior, 1979).

The vegetation of the Great Dismal Swamp continues to change, and the rate of change has accelerated as we approach the 21st century. Beginning about 12,000 B.P. Native Americans begin to have impact on the swamp. By the woodland period (ca. 1,000 B.P.), their fires, cutting and agricultural activities began to make recognizable impacts on the Great Dismal (Bottoms and Painter, 1979).

Early European colonists accelerated the destruction of the virgin swamp. By the 20th century, areas in the swamp had been logged two or three times and perhaps most important, ditch and road construction may have irreversibly altered the swamp's hydrographic regime. The "Green Sea" first mentioned by Byrd in 1728 (Byrd, 1958) had become only a label on the 1977 topographic map of the City of Chesapeake. Much of this once vast reed-dominated community now only exists under the canopy of periodically flooded, upland, hardwood swamps. Other portions are covered by shopping centers and subdivisions.

The "mysterious lights" described by Dean (1969) have changed to red maple - swamp black gum forests. Gone are the forests of giant cypress trees; only their scattered stumps can be seen today. The extensive stands of Atlantic white cedar which once supplied millions of shingles to the market places of a growing American economy have been reduced to scattered remnant stands.

The Great Dismal Swamp National Wildlife Refuge, exists today as a product of the conservation activism of the 1970's. We may no longer have to be concerned that any of the numerous get rich quick schemes that have been proposed since Byrd first recommended that the, "horrible desert" which was "... a blot on His Majesty's Kingdom.", be drained (Byrd, 1958), will be brought to fruition. With careful management, some day our grandchildren may be able to experience some aspects of what George Washington described in his letters to Light Horse Harry Lee (Fitzpatrick, 1925) as "a paradise".

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The Upland Plant Communities of Seashore State Park, Virginia Beach, Virginia

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ABSTRACT

Seashore State Park is a 1086 ha fragment of natural habitat surrounded by the urban portion of Virginia Beach City. During 1989, quantitative data were collected on the plant communities of Seashore. Multivariate analysis of these data identified eight upland community types: mesic forest (*Pinus taeda* / *Acer rubrum* / *Persea borbonia*), dune forest (*Carya* spp. - *Pinus taeda* / *Symplocos tinctoria*), dune woodland (*Pinus taeda* / *Quercus nigra* / *Sassafras albidum*), maritime forest (*Pinus taeda* / *Quercus virginiana*), maritime grassland (*Uniola paniculata* - *Panicum amarulum*), dune grassland (*Panicum amarulum* - *Iva imbricata*), foredune (*Ammophila breviligulata* - *Cakile edentula*), and dune crest (*Hudsonia tomentosa* - *Cyperus grayi*). Several of these community types are rare in Virginia. The structure, composition, environmental setting, and interrelationships of these communities are discussed.

INTRODUCTION

Seashore State Park (hereafter Seashore) is a 1086 ha natural landscape surrounded by the rapidly-growing City of Virginia Beach. Seashore is the most heavily used of Virginia's State Parks, with an annual visitation of over 1 million people. Among Virginia's State Parks, Seashore also supports the highest known concentration of rare species: 37 plants, 7 vertebrates, and at least 20 invertebrates (Clampitt et al., 1990, Wright et al., 1990).

The Department of Conservation and Recreation's Division of State Parks is currently revising the resource management plan for Seashore. To ensure that the plan considers the significance and management needs of Seashore's biological resources, the Division of Natural Heritage conducted a study of communities and rare species that occur there (Clampitt et al., 1990). The goal of the research reported here was to classify and describe the upland plant communities of Seashore.

STUDY SITE

Lying adjacent to the Atlantic Ocean, Seashore has a maritime climate (Soil Conservation Service, 1985). The average annual temperature is 15° C with an average daily high in July of 30° C and an average daily low of 0° C in January. The area receives an average annual precipitation of 112 cm, which falls almost entirely as rain (Soil Conservation Service, 1985).

Seashore is located on Cape Henry, which has formed in geologically recent times from marine sands. The current landscape has resulted from the interaction of wind, water and vegetation on the coastal sands. A generalized cross section of the Cape from north to south would show a series of parallel dunes 2 to 3 m tall

along the shore. Inland of these is the Great Dune, which rises in places to ca. 30 m above sea level. Behind the Great Dune are older, stabilized dunes up to 3 m tall. Although these dunes generally form a series of concentric arcs, this pattern is broken at irregular intervals, and smaller radial dunes connect parallel dunes. The crests of the dunes are well-drained, but the swales between the dunes hold water for much of the year.

The soils of Seashore fall into two general categories (Soil Conservation Service, 1985). The Newhan-Duckston-Corolla group includes excessively drained to poorly drained sandy soils along the Atlantic coast. The Pamlico-Fripp-Lakehurst Variant group includes excessively drained to moderately well drained sandy (Fripp and Lakehurst Variant) soils and very poorly drained organic (Pamlico) soils that lie landward of the former group. Three of the soils mapped within Seashore (Lakehurst Variant, Fripp and Newhan) are thermic, uncoated Typic Quartzipsamments. The Corolla soil is a thermic, uncoated Typic Quartzipsamments and the Pamlico soil is a sandy or sandy-skeletal, siliceous, dysic, thermic Terric Medisaprist (Soil Conservation Service, 1985).

Cape Henry has been of interest to botanists throughout this century (Kearney, 1901; Egler, 1942; Wright, et al., 1990). Although these reports include narrative descriptions of the upland communities on the Cape, few quantitative data have been collected. The sole exception appears to be a brief visit in 1987 by A. Greller and S. Ware, who collected data on the composition of the forest canopy along the Osmanthus Trail (unpubl. data).

METHODS

Field Investigation.

Field work was conducted in two stages: reconnaissance and quantitative sampling. Based on aerial photographs (Virginia Department of Transportation 1:12000 B/W and USGS National High-Altitude Photography 1:24000 CIR), the soil survey, and other sources, Seashore was divided into zones for general reconnaissance. The goal was to gain an understanding of the vegetation patterns present within each zone and to ensure that the full range of vegetation was sampled. During the reconnaissance visits, general notes were made on the composition of the vegetation, the relationships between the plants and the physical environment, and any disturbances present.

Based on the reconnaissance, 10 m X 10 m vegetation plots were established in representative areas. The locations of these plots were pinpointed on a topographic map and the profile of the plot was sketched. The following vegetation data were collected:

- 1) a list of the plant species present in and near the plot (nomenclature for the vascular plants follows Radford et al., 1968);
- 2) the cover of each plant species in the canopy, the sub-canopy, the tall (> 1 m) shrub layer, and the low shrub and herb layer; and
- 3) the diameter at breast height (dbh) of all trees more than 5 cm dbh.

Cover classes used here were:

- 1 < 1%;
- 2 1 to < 5%;

3	5 to <25%
4	25 to <50%;
5	50 to <75%; and
6	75 to 100%.

Cover values near the low or high end of the class were indicated, respectively, by a - or a +.

A soil auger was used to sample the soil at the center of each plot. The soil horizons, presence of organic matter, and apparent soil moisture (e.g., saturated, moist, dry) were noted.

Data Analysis.

For analysis, the vegetation data were converted to a species X plot abundance matrix, with each species assigned the greatest cover that it had in the plot (e.g., if *Pinus taeda* was present as cover class 3 in the canopy and cover class 2 in the subcanopy, it was recorded as cover class 3). Two-Way Indicator Species Analysis (TWINSPAN; Hill, 1979) was used to create a preliminary classification of the community types represented in the data set. This classification was subjectively refined on the basis of field observations.

The diameter data were summarized for each community type identified in the previous step using the PC-ORD package (McCune, 1987). From the data, PC-ORD calculated the basal area per ha, number of trees per ha (density) and frequency of occurrence within the plots. Based on these values, an Importance Value (IV) was calculated for each species in each community type.

RESULTS AND DISCUSSION

Based on the TWINSPAN analysis of the cover data, eight community types were identified at Seashore. Four of these types are dominated by trees (mesic forest, dune forest, dune woodland, and maritime forest), three are graminoid types (maritime grassland, dune grassland, and foredune), and the last (dune crest) is a sparse dwarf-shrub community. The floristic relationships among these types, as determined by TWINSPAN, is depicted in Figure 1. The following descriptions of the upland community types identified in this study are based on the quantitative data (Tables 1 - 12) as well as qualitative field observations. The Natural Heritage State Rank (Lipford et al., 1987) of each type is noted parenthetically after its name. These ranks are also given for rare species mentioned.

Mesic forests (S5) are species-rich stands of mesophytes such as *Oxydendrum arboreum*, *Fagus grandifolia* and *Quercus alba* (Tables 1, 2). Canopy dominants include *Pinus taeda*, *Acer rubrum*, *Quercus nigra*, and *Oxydendrum arboreum*. The sub-canopy is composed of *Ilex opaca* and saplings of the canopy hardwoods. Tall shrubs common in this community type are *Persea borbonia*, *Clethra alnifolia*, *Amelanchier* sp., and *Symplocos tinctoria*. The rare shrub, *Osmanthus americana* (G5/S1), is found almost exclusively in this community type. The herb layer is sparse, with *Vaccinium vacillans* and *Mitchella repens* forming extensive, low mats. *Pteridium aquilinum* can also be present. *Tillandsia usneoides* (G5/S2) occurs in many stands of this community type. *Vitis rotundifolia* and *Smilax glauca* are common vines.

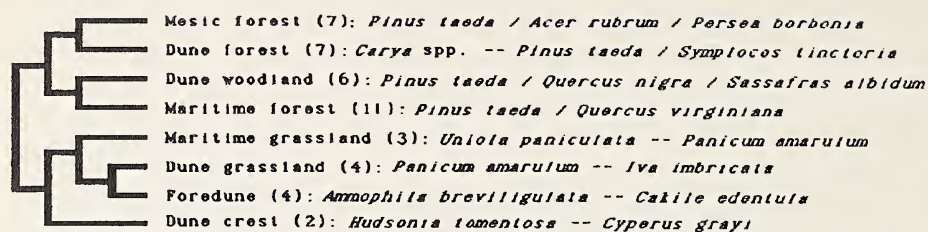


FIGURE 1. Dendrogram showing the relationships among the eight upland community types at Seashore as identified by TWINSPLAN. The natural community name is followed by the number of plots and a provisional association name derived from the vegetation.

TABLE 1. Composition of the canopy and subcanopy of the seven mesic forest plots at Seashore.

Species	%	Density Trees/ha	Basal Area dm ² /ha	Relative %			
	Freq.			Freq.	Dens.	Dom.	I.V.(%)
<i>Acer rubrum</i>	100.00	185.71	456.22	14.89	13.83	15.11	14.61
<i>Carya glabra</i>	14.29	28.57	30.17	2.13	2.13	1.00	1.75
<i>Cornus florida</i>	14.29	57.14	83.35	2.13	4.26	2.76	3.05
<i>Fagus grandifolia</i>	42.86	100.00	208.56	6.38	7.45	6.91	6.91
<i>Ilex opaca</i>	71.43	157.14	93.84	10.64	11.70	3.11	8.48
<i>Liquidambar styraciflua</i>	42.86	42.86	268.82	6.38	3.19	8.90	6.16
<i>Magnolia virginiana</i>	28.57	42.86	61.97	4.26	3.19	2.05	3.17
<i>Nyssa sylvatica</i>	14.29	14.29	116.33	2.13	1.06	3.85	2.35
<i>Osmanthus americana</i>	28.57	57.14	25.69	4.26	4.26	0.85	3.12
<i>Oxydendrum arboreum</i>	85.71	171.43	185.50	12.77	12.77	6.14	10.56
<i>Persea borbonia</i>	57.14	114.29	52.39	8.51	8.51	1.74	6.25
<i>Pinus taeda</i>	57.14	85.71	990.51	8.51	6.38	32.81	15.90
<i>Quercus nigra</i>	71.43	228.57	406.32	10.64	17.02	13.46	13.71
<i>Sassafras albidum</i>	28.57	42.86	34.29	4.26	3.19	1.14	2.86
<i>Symplocos tinctoria</i>	14.29	14.29	5.19	2.13	1.06	0.17	1.12
Totals		1342.86	3019.16	100.02	100.00	100.00	100.00

Within Seashore, mesic forests develop on low dune ridges and along the lower slopes of large dunes, presumably where the trees are able to penetrate the water table over much of the growing season. These communities have distinct downslope boundaries with forested wetlands. Upslope they grade into dune forest. The soils underlying these communities are mapped as Fripp sand, Lakehurst Variant sand, Newhan fine sand, and Pamlico-Lakehurst Variant complex (Soil Conservation Service, 1985).

Although unusual, the presence of *Osmanthus americana* appears to be only a minor variation of a common Coastal Plain community type. Largely because of their limited extent, the stands of this community type at Seashore were not deemed to be of statewide significance.

Dune forests (S1S2) are medium-height forests of drought-tolerant species of *Quercus*, *Carya* and *Pinus* (Tables 3, 4). Although *Pinus taeda* has a greater basal area than any other species, it is surpassed by the combined basal area of the other dominant genera. The oaks are represented in this community type by *Quercus*

nigra and *Q. falcata*, while the hickories include *C. glabra*, *C. ovalis*, and *C. tomentosa*. Common small trees include *Acer rubrum*, *Ilex opaca*, and *Oxydendrum arboreum*. *Symplocos tinctoria* is the characteristic tall shrub. Other tall shrubs that regularly occur in this community type are *Amelanchier* sp. and *Cornus florida*. Herbs are sparse, but *Mitchella repens* often forms expansive mats on the forest floor. Other common low shrubs are *Persea borbonia* and *Gaylussacia baccata*.

Dune forests form on low dune ridges and on the lower slopes of the Great Dune and other high dunes. Dune forests are typically bounded downslope by forested wetlands. In places they grade into mesic forest. Upslope they grade into dune woodland. The soils underlying these forests are primarily mapped as Fripp sand, Newhan fine sand, and Pamlico-Lakehurst Variant complex (Soil Conservation Service, 1985). The dune forests at Seashore apparently represent a rare type in Virginia and therefore are of statewide significance.

Dune woodlands (S1S2) are open-canopy woodlands of the Great Dune and other high dunes (Tables 5, 6). *Quercus nigra* dominates the canopy, with *Pinus taeda* being the only other regularly-occurring canopy tree. *Sassafras albidum* generally occurs as a small tree or tall shrub, while *Ilex opaca* occurs less frequently. *Pteridium aquilinum* is the characteristic herbaceous species, but it rarely provides substantial ground cover.

The dunes supporting this community are generally stable, but the droughty soils apparently make them inhospitable to most plant species. Dune woodlands abruptly border, or grade into, dune forests or, less commonly, dune crests. Dune woodland is perhaps the most highly fragmented of the community types identified during this study. The soils underlying these forests are primarily mapped as Fripp sand and Newhan fine sand (Soil Conservation Service, 1985).

The dune woodlands of Seashore are significant for several reasons. First, they represent a rare community type in Virginia, second they support several rare plants. Among the rare plants found in this community are: *Desmodium strictum* (G2G4/S2), *Quercus hemisphaerica* (G5/S2), *Quercus incana* (G5/S2), *Quercus margarettae* (G5/S2), and *Stipulicida setacea* (G4G5/S1).

Maritime forests (S2S3) consist of dense shrub thickets to open forests of trees up to 10 m tall (Tables 7,8). Dominant species on the ocean side are *Quercus virginiana* and *Q. incana*. Inland, *Pinus taeda* emerge above the oaks. Additional small trees are *Ilex opaca* and *Prunus serotina*. Shrubs provide little cover, but *Sassafras albidum* and *Myrica pensylvanica* are encountered frequently. The herb layer is sparse, but relatively rich in species. Characteristic species include *Opuntia compressa*, *Heterotheca graminifolia*, and *Andropogon virginicus*. Vines are common, but rarely abundant. Among them are *Smilax glauca*, *Gelsemium semper-virens*, *Parthenocissus quinquefolia*, and *Vitis rotundifolia*, which was found in all plots sampled.

Maritime forests form the coastal border of upland forests. At Seashore, they form a gradual transition between the maritime grasslands and the dune forests or dune woodlands. Salt-laden winds apparently prune the trees to create a wedge of vegetation that starts as a low scrub thicket in the lee of a dune and rises to the more typical inland canopy height. The soils of this community type are mapped as Newhan-Corolla fine sands and Newhan fine sand (Soil Conservation Service, 1985).

TABLE 2. Cover data from the seven mesic forest plots, by stratum. Numerical values are cover classes described in the text, a + indicates that the species was present in the vicinity of the plot.

Stratum	Plots							Frequency
Species	60	61	62	65	69	72	109	
Canopy								
<i>Pinus taeda</i>	3+	+	4	3	2	3	3	7
<i>Liquidambar styraciflua</i>					4-	4+		2
<i>Carya glabra</i>	+	3-						2
<i>Nyssa sylvatica</i>		+					3-	2
<i>Quercus nigra</i>		4-						1
<i>Acer rubrum</i>		4-						1
<i>Quercus falcata</i>	3							1
<i>Oxydendrum arboreum</i>		3-						1
Sub Canopy								
<i>Acer rubrum</i>	4-		3-	3-	3	3	5-	6
<i>Ilex opaca</i>	3	3-			2	3-		4
<i>Cxydendrum arboreum</i>	3+		3	2+			3	4
<i>Fagus grandifolia</i>					3	4-	3-	3
<i>Quercus nigra</i>			3+	3+		3		3
<i>Persea borbonia</i>	2	2+	3-					3
<i>Sassafras albidum</i>	3-				2			2
<i>Symplocos tinctoria</i>		2-	3+					2
<i>Magnolia virginiana</i>						3	2+	2
<i>Cornus florida</i>					4+			1
<i>Liquidambar styraciflua</i>			3-					1
<i>Pinus taeda</i>					2			1
<i>Osmanthus americana</i>	2+							1
Vines & Epiphytes								
<i>Vitis rotundifolia</i>	2	3+	2+	2+		1	2	6
<i>Smilax glauca</i>	+	1	3-	2+				4
<i>Rhus radicans</i>			+		2		+	3
<i>Tillandsia usneoides</i>	1	1		1				3
<i>Smilax rotundifolia</i>	2+	2-						2
<i>Parthenocissus quinquefolia</i>	+			1				2
<i>Gelsemium sempervirens</i>			1					1
Shrub Layer								
<i>Persea borbonia</i>	2	2	3	1	2	2+	3	7
<i>Ilex opaca</i>	2	2	2	3	2+	2+	2	7
<i>Clethra alnifolia</i>	4-	4+	2+		3-	2+	4-	6
<i>Quercus nigra</i>	2-	2-		2	+			4
<i>Osmanthus americana</i>	2	2		4-				3
<i>Symplocos tinctoria</i>		2-	3-	2+				3
<i>Fagus grandifolia</i>					1	3-	2	3
<i>Amelanchier</i> sp.		2		2+			2	3
<i>Magnolia virginiana</i>						2	2	2
<i>Acer rubrum</i>		2		2+				2
<i>Oxydendrum arboreum</i>	2				2+			2
<i>Liquidambar styraciflua</i>	2-	1						2
<i>Juniperus virginiana</i>		1		1				2
<i>Euonymus americana</i>		1	1					2
<i>Vaccinium corymbosum</i>		3-						1
<i>Hamamelis virginiana</i>		2-						1
<i>Quercus falcata</i>			2					1
<i>Carya</i> sp.				2-				1
<i>Cornus florida</i>					2+			1
<i>Vaccinium stamineum</i>							2	1

TABLE 2. *contued*

Stratum	Plots							Frequency
Species	60	61	62	65	69	72	109	
Shrub Layer- <i>cont.</i>								
<i>Pinus taeda</i>		1						1
<i>Castanea pumila</i>		1						1
<i>Quercus phellos</i>					1			1
<i>Quercus alba</i>							1	1
Herb Layer								
<i>Vaccinium vacillans</i>	4-	4-	2+	2	2+			5
<i>Clethra alnifolia</i>	3+		2+	2		2+	3	5
<i>Pteridium aquilinum</i>	2	2+		2-	1		1	5
<i>Mitchella repens</i>	2+	4		5-		+		4
<i>Persea borbonia</i>	2+	2				2	2+	4
<i>Osmanthus americana</i>	2	2-		4				3
<i>Quercus nigra</i>		2	1		1			3
<i>Acer rubrum</i>	1	1	1					3
<i>Conopholis americana</i>		+	1	1				3
<i>Symplocos tinctoria</i>			3		1			2
<i>Pinus taeda</i>		1		1				2
<i>Quercus phellos</i>					1		1	2
<i>Amelanchier</i> sp.				2-				1
<i>Fagus grandifolia</i>							2	1
<i>Ilex opaca</i>							2	1
<i>Goodyera pubescens</i>	1							1
<i>Hamamelis virginiana</i>		1						1
<i>Euonymus americanus</i>		1						1
<i>Polypodium polypodioides</i>				1				1
<i>Carya</i> sp.					1			1
<i>Tipularia discolor</i>						1		1
<i>Monotropa uniflora</i>							1	1

TABLE 3. Composition of the canopy and subcanopy of the seven dune forest plots at Seashore.

Species	%	Density Trees/ha	Basal Area dm ² /ha	Relative %			
	Freq.			Freq.	Dens.	Dom.	I.V.(%)
<i>Acer rubrum</i>	71.43	185.71	157.00	11.90	15.29	6.62	11.27
<i>Carya glabra</i>	14.29	57.14	264.81	2.38	4.71	11.17	6.09
<i>Carya ovalis</i>	71.43	100.00	272.64	11.90	8.24	11.50	10.55
<i>Carya tomentosa</i>	14.29	14.29	6.83	2.38	1.18	0.29	1.28
<i>Cornus florida</i>	42.86	71.43	32.07	7.14	5.88	1.35	4.79
<i>Ilex opaca</i>	71.43	142.86	62.35	11.90	11.76	2.63	8.77
<i>Liquidambar styraciflua</i>	28.57	85.71	129.74	4.76	7.06	5.47	5.76
<i>Osmanthus americana</i>	14.29	85.71	24.95	2.38	7.06	1.05	3.50
<i>Ostrya virginiana</i>	28.57	28.57	10.72	4.76	2.35	0.45	2.52
<i>Oxydendrum arboreum</i>	42.86	42.86	35.35	7.14	3.53	1.49	4.05
<i>Pinus taeda</i>	57.14	71.43	657.22	9.52	5.88	27.73	14.38
<i>Quercus falcata</i>	42.86	100.00	396.52	7.14	8.24	16.73	10.70
<i>Quercus nigra</i>	57.14	171.43	290.39	9.52	14.12	12.25	11.96
<i>Symplocos tinctoria</i>	42.86	57.14	29.67	7.14	4.71	1.25	4.37
Totals		1214.29	2370.25	99.96	100.01	99.98	99.99

TABLE 4. Cover data from the seven dune forest plots, by stratum. See Table 2 for details.

Stratum	Plots							Frequency
Species	24.1	24.2	64	101	102	105	110	
Canopy								
<i>Pinus taeda</i>	3-	2	2-	3+	3-	2+		6
<i>Carya</i> sp.	4		4-		3	5-	2+	5
<i>Quercus falcata</i>			+	+	3+	3+	3	5
<i>Pinus echinata</i>					+		2	2
<i>Quercus nigra</i>		5-						1
<i>Liquidambar styraciflua</i>			3-					1
<i>Ilex opaca</i>		2						1
Sub Canopy								
<i>Acer rubrum</i>			2+	3	3-	2+	3+	5
<i>Ilex opaca</i>	3-	3-	3-					3
<i>Quercus nigra</i>			2		3-		3	3
<i>Ostrya virginiana</i>	3-						2+	2
<i>Liquidambar styraciflua</i>				3+		2+		2
<i>Carya</i> sp.				3+		2+		2
<i>Oxydendrum arboreum</i>			2-				2	2
<i>Osmanthus americana</i>			4-					1
<i>Fagus grandifolia</i>		3-						1
<i>Symplocos tinctoria</i>				3-				1
<i>Quercus falcata</i>						3		1
Vines and Epiphytes								
<i>Tillandsia usneoides</i>	2	2	2	2+	1		1	6
<i>Vitis rotundifolia</i>	1	2	2		2	2	1	6
<i>Gelsemium sempervirens</i>	1		2-	+	1			4
<i>Smilax rotundifolia</i>	2	2						2
<i>Rhus radicans</i>	1					1		2
<i>Smilax glauca</i>						1		1
Shrub Layer								
<i>Symplocos tinctoria</i>	1	2	2+	2+	2	3-	2	7
<i>Oxydendrum arboreum</i>		3-	2	2	2		2	5
<i>Ilex opaca</i>			2	2	3	1	2+	5
<i>Cornus florida</i>				1	2	3+	3	4
<i>Amelanchier</i> sp.	2-		2	1		2		4
<i>Quercus nigra</i>	2		3-	2				3
<i>Acer rubrum</i>		2	2+	2				3
<i>Hamamelis virginiana</i>	3	4				2		3
<i>Persea borbonia</i>		2	+					2
<i>Clethra alnifolia</i>		4						1
<i>Osmanthus americana</i>			4					1
<i>Ostrya virginiana</i>							3-	1
<i>Carya</i> sp.				2				1
<i>Castanea pumila</i>					1			1
<i>Juniperus virginiana</i>			+					1
<i>Quercus incana</i>			+					1
<i>Sassafras albidum</i>							+	1
Herb Layer								
<i>Mitchella repens</i>	5	3-	5	5	4+		3	6
<i>Quercus nigra</i>	1	1			1	2	1	5
<i>Persea borbonia</i>	1	1		1		1	1	5
<i>Gaylussacia baccata</i>	3-	2	3		4+			4
<i>Pinus taeda</i>			1	1	1	1		4
<i>Vaccinium vacillans</i>	1	3					2	3
<i>Acer rubrum</i>	1	1	2-					3

TABLE 4. -continued

Stratum	Plots							Frequency
Species	24.1	24.2	64	101	102	105	110	
Herb Layer-cont.								
<i>Clethra alnifolia</i>		1	1				2	3
<i>Conopholis americana</i>		1	1				1	3
<i>Vaccinium stamineum</i>				2		4+		2
<i>Castanea pumila</i>						1	2+	2
<i>Symplocos tinctoria</i>				2-		1		2
<i>Ilex opaca</i>		1				2		2
<i>Monotropa uniflora</i>	1						1	2
<i>Amelanchier</i> sp.	1	1						2
<i>Carya</i> sp.		1				1		2
<i>Panicum</i> sp.				1		1		2
<i>Sassafras albidum</i>				1	1			2
<i>Polygonatum pubescens</i>	+	1						2
<i>Myrica</i> sp.				+			1	2
<i>Hamamelis virginiana</i>	2							1
<i>Osmanthus americana</i>			2+					1
<i>Quercus falcata</i>					2			1
<i>Gaylussacia frondosa</i>				2+				1
<i>Vaccinium</i> sp.						2		1
<i>Carex nigra</i>	1							1
<i>Uvularia sessilifolia</i>	1							1
<i>Oxydendrum arboreum</i>							1	1
<i>Pinus echinata</i>						1		1
<i>Tipularia discolor</i>						1		1
<i>Pteridium aquilinum</i>						1		1
<i>Quercus phellos</i>			+					1

TABLE 5. Composition of the canopy and subcanopy of the six dune woodland plots at Seashore.

Species	%	Density Trees/ha	Basal Area dm ² /ha	Relative %			
	Freq.			Freq.	Dens.	Dom.	I.V.(%)
<i>Carya tomentosa</i>	16.67	16.67	4.71	7.69	1.18	0.29	3.05
<i>Pinus taeda</i>	66.67	300.00	754.28	30.77	21.18	46.82	32.92
<i>Quercus falcata</i>	16.67	33.33	46.71	7.69	2.35	2.90	4.31
<i>Quercus nigra</i>	83.33	1033.33	792.12	38.46	72.94	49.17	53.52
<i>Sassafras albidum</i>	33.33	33.33	13.22	15.38	2.35	0.82	6.19
Totals		1416.67	1611.05	99.99	100.00	100.00	99.99

TABLE 6. Cover data from the six dune woodland plots, by stratum. See Table 2 for details.

Stratum	Plots						Frequency
Species	57	103	111	112	113	114	
Canopy							
<i>Pinus taeda</i>	4	2-	+	4-	4	1	6
<i>Quercus nigra</i>		3+	3+	4-	3+	5-	5
<i>Quercus falcata</i>		+		3-			2
<i>Carya tomentosa</i>		2					1
<i>Oxydendrum arboreum</i>			+				1
<i>Ilex opaca</i>						+	1
Vines and Epiphytes							
<i>Gelsemium sempervirens</i>	3-	3		3	1	3	5
<i>Vitis rotundifolia</i>	1	3	1			2	4
<i>Smilax bona-nox</i>	2+				1		2
<i>Smilax glauca</i>	1			1			2
<i>Vitis aestivalis</i>	+					+	2
<i>Smilax rotundifolia</i>				2			1
Shrub Layer							
<i>Sassafras albidum</i>	3	1	2	1	3-	2	6
<i>Pinus taeda</i>	2+	1			2		3
<i>Ilex opaca</i>		+			1		2
<i>Quercus incana</i>						3	1
<i>Quercus falcata</i>	2						1
<i>Quercus nigra</i>			2				
<i>Symplocos tinctoria</i>		2					1
<i>Castanea pumila</i>		2					1
<i>Vaccinium corymbosum</i>				2-			1
<i>Diospyros virginiana</i>				2-			1
<i>Vaccinium vacillans</i>						2-	1
<i>Vaccinium sp.</i>	1+						1
<i>Rhus copallina</i>	+						1
Herb Layer							
<i>Sassafras albidum</i>	2	1		1	1		4
<i>Quercus nigra</i>			2+	1	1	1	4
<i>Ilex opaca</i>	1	1	1	1			4
<i>Pteridium aquilinum</i>		2			6	1	3
<i>Pinus taeda</i>	1+				1	1	3
<i>Gaylussacia baccata</i>		4-	6-				2
<i>Vaccinium stamineum</i>				3		3-	2
<i>Diospyros virginiana</i>		2			1		2
<i>Cladina sp.</i>			1	1			2
<i>Monotropa uniflora</i>				1		+	2
<i>Gaylussacia frondosa</i>		4+					1
<i>Andropogon virginicus</i>	2						1
<i>Carex emmonsii</i>	2+						1
<i>Myrica sp.</i>					2		1
<i>Quercus falcata</i>	1						1
<i>Cypripedium acaule</i>		1+					1
<i>Chimaphila maculata</i>	1						1
<i>Hieracium gronovii</i>	1						1
<i>Carya sp.</i>		1					1
<i>Opuntia compressa</i>		1					1
<i>Panicum sp.</i>		1					1
<i>Pinus echinata</i>			1				1
<i>Hamamelis virginiana</i>			1				1
<i>Cnidioscolus stimulosus</i>					1		1
<i>Solidago odora</i>	+						1
<i>Elephantopus sp.</i>	+						1

TABLE 7. Composition of the canopy and subcanopy of the eleven maritime forest plots at Seashore.

Species	%	Density	Basal Area	Relative %			
	Freq.	Trees/ha	dm ² /ha	Freq.	Dens.	Dom.	I.V.(%)
<i>Ilex opaca</i>	27.27	54.55	69.77	11.11	7.41	3.23	7.25
<i>Juniperus virginiana</i>	9.09	9.09	3.80	3.70	1.23	0.18	1.70
<i>Liquidambar styraciflua</i>	9.09	18.18	18.76	3.70	2.47	0.87	2.35
<i>Pinus serotina</i>	9.09	9.09	47.53	3.70	1.23	2.20	2.38
<i>Pinus taeda</i>	63.64	381.82	1300.93	25.93	51.85	60.18	45.99
<i>Prunus serotina</i>	18.18	18.18	5.15	7.41	2.47	0.24	3.37
<i>Quercus incana</i>	27.27	36.36	33.24	11.11	4.94	1.54	5.86
<i>Quercus nigra</i>	9.09	9.09	11.16	3.70	1.23	0.52	1.82
<i>Quercus virginiana</i>	63.64	181.82	663.54	25.93	24.69	30.70	27.10
<i>Sassafras albidum</i>	9.09	18.18	7.69	3.70	2.47	0.36	2.18
Totals		736.36	2161.56	99.99	99.99	100.02	100.00

TABLE 8. Cover data from the eleven maritime forest plots, by stratum. See Table 2 for details.

Stratum	Plots											Freq.
Species	38	41	42	43.1	43.2	44	47	48	49	54	82	
Canopy												
<i>Pinus taeda</i>	5+	3	3+	2			3+	3		4-	3+	8
<i>Quercus virginiana</i>	5	4	3		5+	3	5+	5	3			8
<i>Quercus incana</i>	3	4			4-			3				4
<i>Ilex opaca</i>			2+						3	3-		3
<i>Prunus serotina</i>		2				2						2
<i>Sassafras albidum</i>				2						2+		2
<i>Pinus serotina</i>	3											1
<i>Myrica</i> sp.						3-						1
<i>Quercus nigra</i>							3+					1
<i>Liquidambar styraciflua</i>											3-	1
<i>Juniperus virginiana</i>		2										1
<i>Nyssa sylvatica</i>										2-		1
<i>Acer rubrum</i>											2+	1
Vines and Epiphytes												
<i>Vitis rotundifolia</i>	+	3	3+	2	3-	+	2	3	2	3	3+	11
<i>Smilax glauca</i>			2		1	1	1	2			1	6
<i>Parthenocissus quinquefolia</i>	3		2+	1		2				+		5
<i>Gelsemium sempervirens</i>			1					2	2-		3+	4
<i>Lonicera sempervirens</i>			1	1							+	3
<i>Smilax rotundifolia</i>										2+	5-	2
<i>Smilax bona-nox</i>						+		2				2
<i>Rhus radicans</i>									1	+		2
Shrub Layer												
<i>Sassafras albidum</i>	2		3-				2	2	2+		+	6
<i>Quercus virginiana</i>			4		2		3		2		1	5
<i>Quercus incana</i>	2		4				2	2-	2			5
<i>Quercus nigra</i>						+		2	+	1	2	5
<i>Myrica pensylvanica</i>	3						1			+	2+	4
<i>Vaccinium corymbosum</i>							2-	2		+		3
<i>Juniperus virginiana</i>			1						+			3
<i>Prunus serotina</i>									3-		1	2
<i>Pinus taeda</i>									2		2	2

TABLE 8. *continued*

Stratum	Plots											Freq.
Species	38	41	42	43.1	43.2	44	47	48	49	54	82	
Shrub Layer-cont.												
<i>Persea borbonia</i>										+	+	2
<i>Quercus falcata</i>	3											1
<i>Liquidambar styraciflua</i>											3	1
<i>Acer rubrum</i>											3	1
<i>Ilex opaca</i>									2+			1
<i>Diospyros virginiana</i>									2			1
Herb Layer												
<i>Andropogon virginicus</i>	2			3+	3+	3			2		3-	6
<i>Quercus nigra</i>	1		1	2			1		1	1		6
<i>Heterotheca graminifolia</i>			1	1	1	1		+	1			6
<i>Panicum</i> sp.	1		1				1		1		2-	5
<i>Sassafras albidum</i>					1		1	1			+	4
<i>Quercus incana</i>			2	3-	2							3
<i>Quercus virginiana</i>								2	2+	1		3
<i>Quercus falcata</i>	2			1					1			3
<i>Ilex opaca</i>	1		1						1			3
<i>Prunus serotina</i>		1		1						1		3
<i>Opuntia compressa</i>		1	1						1			3
<i>Pinus taeda</i>			1				1		1			3
<i>Cyperus grayi</i>			1		1				1			3
<i>Galium hispidulum</i>					1				+		1	3
<i>Myrica pensylvanica</i>				3+	3-							2
<i>Vaccinium corymbosum</i>							2-	1				2
<i>Solidago odora</i>									1		1	2
<i>Hieracium gronovii</i>									1		+	2
<i>Mitchella repens</i>											2	1
<i>Panicum amarulum</i>											2-	1
<i>Persea borbonia</i>	1											1
<i>Erigeron canadensis</i>					1							1
<i>Linaria vulgaris</i>					1							1
<i>Astraeus hygrometricus</i>					1							1
<i>Liquidambar styraciflua</i>										1		1
<i>Aira praecox</i>									1			1
<i>Conopholis americana</i>									1			1
<i>Diodia teres</i>											1	1
<i>Carduus spinosissimus</i>						+						1

North of the James River, the character of maritime forests changes markedly with evergreen oaks dropping out almost entirely. For example, the extensive maritime forests along the Eastern Shore are composed of *Pinus taeda* and various deciduous shrubs and vines (pers. obs.).

The maritime forest at Cape Henry has been heavily disturbed by various human activities: the development of a campground at Seashore, military activities at Fort Story, and the construction of residential and commercial buildings on the adjacent private lands. Despite the high level of disturbance, the maritime forests at Seashore are of statewide significance because they are some of the best remaining stands of this type in the Commonwealth.

TABLE 9. Cover data from the three maritime grassland plots, by stratum. See Table 2 for details.

Stratum	Plots			Frequency
Species	87	92	96	
Herb				
<i>Andropogon virginicus</i>	5	3+	2+	3
<i>Uniola paniculata</i>	2+	3+	4-	3
<i>Panicum amarulum</i>		2	3	2
<i>Iva imbricata</i>	2+		2	2
<i>Erigeron canadensis</i>	2+	+		2
<i>Heterotheca graminifolia</i>	+	2-		2
<i>Lactuca</i> sp.	1			2
<i>Diodia teres</i>	1	1		2
<i>Linaria vulgaris</i>	1	1		2
<i>Quercus virginiana</i>	1	1		2
<i>Euphorbia polygonifolia</i>	1	1		2
<i>Carex kobomugi</i>			5	2
<i>Spartina patens</i>	2			1
<i>Cyperus grayi</i>		2-		1
<i>Oenothera humifusa</i>	1			1
<i>Ilex opaca</i>	1			1
<i>Cenchrus tribuloides</i>			1	1

TABLE 10. Cover data from the four dune grassland plots, by stratum. See Table 2 for details.

Stratum	Plots				Frequency
Species	90	90.1	93	94.1	
Herb					
<i>Panicum amarulum</i>	5-	3+	3	2+	4
<i>Iva imbricata</i>	2	2	2+	4	4
<i>Cenchrus tribuloides</i>	1	2	1	1	4
<i>Xanthium strumarium</i>	1	2	1	1	4
<i>Ammophila breviligulata</i>	2	3+	4-		3
<i>Erigeron canadensis</i>	1	1		1	3
<i>Diodia teres</i>		2		1	2
<i>Cakile edentula</i>		1	1		2
<i>Uniola paniculata</i>				4	1
<i>Solidago sempervirens</i>				2	1
<i>Spartina patens</i>	2				1
<i>Euphorbia polygonifolia</i>	1				1
<i>Iva frutescens</i>	1				1
<i>Salsola kali</i>			1		1
<i>Vitis rotundifolia</i>	+				1
<i>Quercus virginiana</i>	+				1
<i>Heterotheca graminifolia</i>	+				1

Maritime grasslands (S5) occur on the dunes and swales inland of the primary dunes. Dominant species include *Andropogon virginicus*, *Panicum amarulum*, and *Spartina patens* (Table 9). Where the sand is less stable, *Uniola paniculata* is also abundant. Growing with the grasses are several herbs and shrubs. Among these are *Linaria canadensis*, *Erigeron canadensis*, *Quercus virginiana*, and *Iva imbricata*.

Maritime grasslands develop on stable to semi-stable dunes. At Seashore, they are bordered on the seaward side by dune grasslands, and on the inland side by

TABLE 11. Cover data from the four foredune plots, by stratum. See Table 2 for details.

Stratum	Plots				Frequency
Species	58	912	94.2	95	
Herb					
<i>Ammophila breviligulata</i>	3+	3	4-	1	4
<i>Panicum amarulum</i>	3	1	3-	1	4
<i>Xanthium strumarium</i>	2-	+	2	2	4
<i>Cakile edentula</i>	2	2	1	1	4
<i>Salsola kali</i>	+	1	1	1	4
<i>Carex kobomugi</i>	2-	1		5	3
<i>Cenchrus tribuloides</i>		1	2	2	3
<i>Diodia teres</i>	1	1	2-		3
<i>Spartina patens</i>			3	1	2
<i>Distichlis spicata</i>		1		1	2
<i>Euphorbia polygonifolia</i>		1	1		2
<i>Strophostyles helvola</i>			1	1	2
<i>Iva imbricata</i>			1	+	2
<i>Uniola paniculata</i>	+			+	2
<i>Solidago sempervirens</i>		1			1

TABLE 12. Cover data from the two dune crest plots, by stratum. See Table 2 for details.

Stratum	Plots		Frequency
Species	38.1	81	
Shrub			
<i>Quercus virginiana</i>	3	2 +	2
<i>Prunus serotina</i>	2		1
<i>Myrica cerifera</i>	1		1
Herb			
<i>Hudsonia tomentosa</i>	3	3-	2
<i>Panicum amarulum</i>	2	2-	2
<i>Cyperus grayi</i>	1	1	2
<i>Pinus taeda</i>	1	1	2
<i>Andropogon virginicus</i>		3	1
<i>Gelsemium sempervirens</i>	2		1
<i>Smilax rotundifolia</i>	1		1
<i>Sassafras albidum</i>	1		1
<i>Panicum sp.</i>	1		1
<i>Campsis radicans</i>	1		1
<i>Quercus nigra</i>	1		1
<i>Opuntia compressa</i>	1		1
<i>Solidago odora</i>		1	1
<i>Astraeus hygrometricus</i>		1	1
<i>Diodia teres</i>		1	1
<i>Krigia dandelion</i>		1	1
<i>Lechea maritima</i>		+	1

maritime forest. In places, the dune grassland, maritime grassland and maritime forest form a mosaic. As with maritime forests, salt spray apparently limits these grasslands to salt-tolerant species. The soils underlying this community type at Seashore are mapped as Newhan fine sands (Soil Conservation Service, 1985). Extensive, pristine maritime grasslands exist on Virginia's barrier islands. The

maritime grassland at Seashore is degraded and small: it is not of statewide significance.

Dune grasslands (S4) form narrow bands of tall grasses along the primary dune. *Panicum amarulum* and *Iva imbricata* (G5/S1S2) occur here in abundance, while the characteristic species are *Uniola paniculata* and *Ammophila breviligulata* (Table 10). Herbs characteristic of the foredune grow where the tall grasses are sparse. Dune grasslands have irregular inland borders with maritime grassland, and rather abruptly border the foredune.

Dune grasslands occur above the high-tide line on the semi-stable primary dune. Blowouts, overwash, and on-shore winds directly influence this community. In places, trails have broken the rhizome mat and de-stabilized this community. Possibly a result of disturbance, *Carex kobomugi*, an exotic sedge, now dominates tens of square meters. This community is underlain by Newhan fine sands (Soil Conservation Service, 1985).

As with the maritime forests, the composition of dune grasslands shifts north of the James River. While *Uniola paniculata* is a common constituent to the south, it is replaced by *Ammophila breviligulata* along Virginia's Eastern Shore (pers. obs.). Although this community is moderately disturbed at Seashore, examples of this type with an abundance of *Uniola paniculata* are rare in Virginia.

The **foredune** (S5) consists of a narrow band of sparsely vegetated sand along the seaward base of the primary dune. Although *Ammophila breviligulata* can be abundant, the characteristic species are low-growing annuals including *Salsola kali*, *Cenchrus tribuloides*, *Cakile edentula*, and *Euphorbia polygonifolia* (Table 11). The foredune has a reasonably sharp boundary with the dune grassland community that lies inland. No vegetated communities exist to the seaward side.

The primary dune bears the full brunt of winter storms, including erosion, deposition, and inundation by saltwater. No true soils develop here, and the substrate of this community is simply mapped as Beach (Soil Conservation Service, 1985).

The **dune crest** (S2S4) community is a largely unvegetated expanse of unstable sand on the crest of the Great Dune. Characteristic species are *Hudsonia tomentosa*, *Cyperus grayi*, and an earth star fungus (Table 12). Woody species are sparse, stunted, and may show evidence of being buried by the shifting dune. Among the woody species found here are *Quercus virginiana*, *Q. nigra*, and *Pinus taeda*. *Panicum amarulum* and *Andropogon virginicus* are often found in patches, especially near the small trees.

The dune crest community occurs on the crest and slopes of the Great Dune that have not been stabilized by vegetation. The dune crest community typically grades into dune woodland and maritime forest, but near the southwestern corner of Seashore it ends abruptly in a brackish marsh. The underlying soil, mapped as Newhan fine sand (Soil Conservation Service, 1985), is droughty and unstable, creating harsh conditions for most plant species.

The dune crest community type is undoubtedly transient in space and time. This community type develops in the least stable sections of active dunefields, and is replaced by other community types as the sand stabilizes. Currently, there are few active dune fields in Virginia, and this community type is rare and declining.

Historical accounts of Cape Henry (e.g., Kearney, 1901) clearly indicate that there have been major changes in the vegetation of this area since Europeans first reached Virginia. The Great Dune appears to have undergone the most radical change. Latrobe (1799) described an unvegetated Great Dune encroaching upon the adjacent swamp forest at a rate of 20 m/yr. A century later, Kearney (1901) described a similar phenomenon, but noted that the rate of encroachment appeared to be substantially less. Kearney also noted that isolated pines were growing "in the middle dunes". His report includes photographs of the Great Dune with essentially no woody vegetation except the tops of *Taxodium distichium* that had been engulfed by the dune. In 1942 Egler reported that the Great Dune was still active and largely unvegetated, except for "extensive patches of *Hudsonia tomentosa*" on the "lower quiescent" portions. Thus, it appears that the maritime forests, dune forests and dune woodlands at Seashore have undergone marked changes over the past half-century. The causes of these changes are unknown, but are likely to be both natural (e.g. increasing separation of the Great Dune and the accreting shoreline) and anthropogenic (road and building construction, trampling, etc.). In light of these changes, future management of the system to protect the natural and recreational values of the Park will present a challenge.

In summary, an analysis of quantitative data on the upland plant communities of Seashore State Park revealed the presence of eight distinct types. These include forests, woodlands, dwarf-scrublands, and grasslands. Five of these types are believed to be of statewide significance in Virginia, and several support rare plants and animals. Locally, the Cape Henry ecosystem is significant because it is the only large, natural landscape unit in the urbanized portion of Virginia Beach. Because this ecosystem is dynamic, well-designed and conducted management will be critical its continued existence.

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JEFFRESS RESEARCH GRANT AWARDS

The Allocations Committee of the Thomas F. and Kate Miller Jeffress Memorial Trust has announced the award of Jeffress Research Grants to the institutions listed below to support the research of the investigator whose name is given. The Jeffress Trust, established in 1981 under the will of Robert M. Jeffress, a business executive and philanthropist of Richmond, supports research in chemical, medical and other natural sciences through grants to non-profit research and educational institutions in the Commonwealth of Virginia. The Jeffress Research Grants being announced here have been awarded in 1991.

The Jeffress Memorial Trust is administered by NationsBank of Virginia, N. A. Additional information about the program of the Trust may be obtained by writing to: Advisor, Thomas F. and Kate Miller Jeffress Memorial Trust, NationsBank, Trust Division, P. O. Box 26903, Richmond, VA 23261.

- S. Laura Adamkewicz, George Mason University. Evolutionary Genetics of Donacid Clams. \$23,997 (two years).
- Sylvia R. Betcher, Virginia Commonwealth University. Sodium-dependent Nucleoside Transport: Effects of 2-Azidoadenosine. \$24,011 (one year).
- David R. Bevan, Virginia Polytechnic Institute and State University. Binding of Carbohydrates to Gliadins. \$23,438 (one year).
- Robert A. Bloodgood, University of Virginia. Transmembrane Signalling in the Chlamydomonas Flagellum. \$15,700 (one year renewal).
- Alan H. Christensen, George Mason University. Promoter Analysis of a Maize Ubiquitin Gene. \$27,115 (two years).
- Gail E. Christie and Catherine H. Roberts, Virginia Commonwealth University. Structural and Functional Characterization of the Transcriptional Activator Protein, Ogr. \$8,400 (one year).
- Fu-lin Chu, College of William and Mary, Virginia Institute of Marine Science. Immune Capacity and Susceptibility of Eastern Oysters, Crassostrea Virginia, to the Pathogen, Perkinsus marinus (Dermo). \$15,000 (one year renewal).
- Gary F. Clark, Eastern Virginia Medical School. Investigation of the Role of Glycoconjugates in Human Sperm - Egg Binding Using the Hemizona Assay System. \$44,490 (three years).
- Randall D. Davy, Liberty University. Stability and Energy of Cyclic Structures of Simple Compounds of Silicon, Sulfur, and Phosphorus. \$17,329 (one year).
- Richard N. Day, University of Virginia. The Regulation of Protein Kinase Inhibitory Protein (PKI). \$40,225 (two years).
- Scott R. Diehl, Virginia Commonwealth University. Molecular Genetic Studies of a Schwannoma Cell Line with a Translocation in the Vicinity of the NFI Gene. \$15,478 (one year).
- M. Samy El-Shall, Virginia Commonwealth University. Studies on Nucleation and Growth in Supersaturated Vapors. \$17,245 (one year renewal).
- David A. Gewirtz and Lawrence Povirk, Virginia Commonwealth University. Site-Specific DNA Damage Induced by Antineoplastic Drugs. \$20,185 (one year).

- Elizabeth Anne Grabau, Virginia Polytechnic Institute and State University. Soybean Mitochondrial Transformation via Microprojectile Bombardment. \$12,888 (one year).
- Jack L. Haar, Virginia Commonwealth University. Isolation of Thymic Factors for Bone Marrow Pre-T Lymphocytes. \$17,505 (one year renewal).
- Steven L. Herr, Virginia Commonwealth University. Bolometric Studies of the Optical Properties of Thin Film High Temperature Superconductors. \$22,073 (one year).
- Barry T. Hinton, University of Virginia. Regulation of Epididymal Gamma-Glutamyl Transpeptidase. \$18,672 (one year renewal).
- Michael P. Holsapple, Virginia Commonwealth University. Activation of B-lymphocytes by TCDD. \$38,999 (one year renewal).
- Laura C. Huang, University of Virginia. In vivo Study of Anabolic Effects of Insulin Mediator. \$29,720 (two years).
- Norbert E. Kaminski, Virginia Commonwealth University. Immunomodulation by Serum Amyloid A Protein. \$31,750 (one year renewal).
- Ivor T. Knight, James Madison University. Investigation of the Stability of Nucleic Acids in Nonrecoverable, Enteropathogenic Bacteria and Their Detection by Hybridization Probes. \$26,980 (two years).
- Rakesh C. Kukreja, Virginia Commonwealth University. Molecular Mechanisms of Oxygen Radicals and Neutrophil-Mediated Myocardial Injury. \$30,366 (two years).
- Barbara J. Mann, University of Virginia. Analysis of the Genes Encoding the Galactose Lectin of *Entamoeba histolytica*. \$27,458 (one year).
- Ravinder K. Mittal, University of Virginia. Role of crucial diaphragm in the prevention of gastrointestinal reflux. \$20,955 (one year).
- Louise B. Montgomery, Marymount University. A Study of Viral Persistence. \$14,625 (one year).
- Roy C. Ogle and John A. Persing, University of Virginia. The Influence of Basement Membranes on Osteogenesis. \$28,288 (one year).
- K. Kevin Pfister, University of Virginia. The Mechanism of Chromosome Movement in Mitosis. \$20,600 (one year).
- Arun J. Sanyal, Virginia Commonwealth University. The Effects of Bile Acids on Iron Absorption. \$16,000 (one year).
- Jerzy Sarosiek, University of Virginia. The Role of Esophageal Mucin-Lipid-Bicarbonate Complex in Mucosal Protection. \$14,200 (one year).
- J. Neel Scarsdale, Jr., Virginia Commonwealth University. NMR Studies of Protein Saccharide Interactions. \$18,900 (one year).
- Beate Schmittmann, Virginia Polytechnic Institute and State University. Non-Equilibrium Dynamics of Driven Multi-Species Lattice Gas Models. \$33,557 (three years).
- John D. Schuetz, Virginia Commonwealth University. Regulation of Cellular Detoxification by P-Glycoprotein in Rat and Human Hepatocytes. \$21,220 (one year renewal).
- Joseph D. Schwartzman, University of Virginia. Motility and Host Cell Invasion of *Toxoplasma gondii*. \$37,413 (one year renewal).

- Robert F. Smith, George Mason University. Neurobehavioral Effects of Prenatal Cocaine. \$19,558 (one year renewal).
- James W. Tanko, Virginia Polytechnic Institute and State University. Interplay of Structure and Reactivity in Atom Abstraction Reactions. \$16,047 (one year).
- Ted S. Thomas, University of Virginia. The Role of SOG in Complement Inhibition. \$29,795 (one year renewal).
- Donna H. Wang, Eastern Virginia Medical School. Microvascular changes in rat cremaster muscle during chronic decreases in blood flow. \$19,100 (one year renewal).
- Grace A. Wyngaard, James Madison University. A Preliminary Analysis of the Role of Ribosomal RNA Genes in Chromatin Diminution. \$16,995 (one year renewal).
- Vicki H. Wysocki, Virginia Commonwealth University. Fundamentals of Collisions of Polyatomic Ions with Surfaces. \$11,660 (one year renewal).

VIRGINIA ACADEMY OF SCIENCE
EXECUTIVE COMMITTEE MINUTES

May 22, 1991 Virginia Tech

Present: Richard Brandt (President), Gerald Taylor (President-Elect), Elsa Falls (Secretary), Jim Martin (Editor VJS), R. Dean Decker (VJAS), Michael L. Bass (Immed. Past-President), Carvel Blair (Long-Range Planning Committee)

The meeting was called to order at 11 a.m. by President Richard Brandt.

Approval of Executive Committee Minutes of March 2, 1991.

The minutes of the Executive Committee Meeting of March 2, 1991, were approved as distributed.

President's Report by Richard Brandt.

1. The President reported that the proposed By-Laws changes to Article 3, to have one person nominated by the Nominating Committee for each office, will be presented by Frank Leftwich, Chairman of the Constitution and By-Laws Committee, and voted on at the afternoon Council Meeting.

2. He reported that business at the afternoon Council Meeting will include the reading of a letter to Harold Bell thanking him for his fine work as Director of the Visiting Scientists program, the reading of a letter from Governor Wilder congratulating VJAS on the occasion of its fiftieth anniversary, the reading of a letter to Martha Roane designating her as a Fellow of the Academy, and announcements concerning awarding of VAS Life Memberships.

3. A letter has been received from Arthur Burke, Chairman of the Finance and Endowment Committee, indicating that the Academy is financially sound. The letter will be read at the Academy Conference on Thursday.

4. Ballots for new Academy officers will be counted during the afternoon Council Meeting.

5. The 1992 VAS Meeting will be held at University of Richmond, as confirmed by a letter from UR Provost Zeddie Bowen.

6. A letter will be read at the afternoon Council Meeting appointing Dr. William L. Banks, Jr. to represent VAS for another term on the Allocations Committee of the Thomas F. Jeffress and Kate Miller Jeffress Memorial Trust and the Richard Gwathmey and Caroline T. Gwathmey Trust.

7. The State Education Committee of the American Cancer Society has provided \$500 in prize money and certificates for outstanding VJAS papers related to cancer research and has promised to contribute \$1000 for the 1992 Meeting.

8. Over \$18,000 has been received from GMU as income from the 1990 Annual Meeting, but their final report has not been received. Gerald Taylor stated his need, as President-Elect, for reports from the last several Annual Meetings.

Local Arrangements Committee Report.

In the absence of Golde Holtzman, Chairman, the President announced that the Meeting was running smoothly thus far.

President-Elect's Report by Gerald Taylor.

Dr. Taylor's report (attached) included the following information:

1. Letters sent to approximately 1100 VAS members asking them to recruit new members resulted in less than a 3% response. Michael Bass commented that he had just received the letter, which had been mailed some weeks earlier.

2. The Computer Science Section and the Archaeology Section are holding their first meetings. The Agriculture Section is holding a business meeting, and the Engineering Section is not meeting.

3. 395 papers will be presented at Senior Academy meetings this week. Three symposia are being held: Biotechnology at Work, Geology in Virginia's Museums, and Land Use Patterns and Impacts on the Biota of Virginia.

Jim Martin pointed out the necessity of adding the names of new Sections to the Constitution and asked what procedure must be followed. Richard Brandt asked him to bring up the question at the afternoon Council Meeting.

Past President's Report by Michael Bass.

He indicated that he was successful in getting one of two additional exhibitors whom he approached and that the exhibit space is completely filled.

He has received a letter notifying him officially that he is the VAS representative and advisory member to a state committee which has submitted an NSF grant proposal to promote education in mathematics and science in Virginia, but there has been no word on whether or not the proposal will be funded.

Virginia Junior Academy of Science Report by Dean Decker.

Dr. Decker stated that the meeting is going well. In honor of the fiftieth anniversary of VJAS, mugs and tee shirts are being sold, and commemorative pencils will be given to all Meeting registrants.

He described plans for this evening's VJAS fiftieth anniversary celebration which will begin with a VJAS/VAS Joint General Session at 8 p.m.; his script will be available for anyone who is interested. Philip Morris will be recognized for its ongoing support of VJAS through the donation of prize money for winners in various Sections for at least twenty-five years. Six of thirteen directors of VJAS will be present and recognized. The celebration is being financed through a \$1000 donation from Philip Morris and \$2000 approved by Council. The program will include a history of VJAS with accompanying slides put together by Eleanor Tenney, information about former VJAS officers, and the introduction of former award and scholarship winners who are present. Sheet cakes have been ordered for the VJAS dance and the VAS reception, which will follow the Joint General Session.

The VAS reception will be held at the Museum of Natural History, and directions to the Museum must be provided for those who are interested in attending.

Virginia Journal of Science Report by Jim Martin, Editor.

Dr. Martin reported that he is over his budget of approximately \$14,000; the first Journal volume billed this year was a unusually large two-part issue costing \$10,000 and included proceedings from a symposium on barrier islands, which had been expected much earlier. The second volume cost \$4,900. Two more volumes (including one with Annual Meeting abstracts) are yet to be published this year. It will be necessary to get the approval of Council for expenditures beyond budget, estimated at \$8,000.

Dr. Taylor asked where the money will come from for publication of a directory and stated it should not come out of the Journal budget. He suggested that publication of abstracts and directory costs should be included as part of the Annual Meeting costs.

President Brandt announced that Treasurer Carolyn Conway was absent because she was judging VJAS papers, but she plans to give a report on Academy finances at the Council Meeting on Friday.

The meeting was adjourned by the President at 12:05 p.m.

Respectfully submitted by :

Elsa Q. Falls, Secretary

Virginia Academy of Science

VIRGINIA ACADEMY OF SCIENCE COUNCIL MINUTES

May 22, 1991 Virginia Tech

Present: Richard Brandt (President), Gerald Taylor, Jr. (President-Elect), Michael L. Bass (Immediate Past-President), James P. O'Brien (Psy. Sec. Rep., Virginia Scientists Editor, Chair Ad Hoc News & Info. Comm.) Gregory C. Cook (Acting Secretary, Comp. Science Section), Carvel Blair (Chair, Ad Hoc Comm. on Environ; Councilor of Environ. Sci. Section), B. M. Bruner (Exec. Secretary-Treas.), Frank Leftwich (Chair, Const. & By-Lays Comm.), George Mushrush (Chair, Chem. Section), Kenneth C. Jacobs (Councilor, Astronomy-Math-Physics Section), Harold M. Bell (Director, Visiting Scientist Program), Martha K. Roane (Archives and Flora Committees), Jim Martin (Editor, VJS), Ertle Thompson (AAAS Rep. & Science Educ. Comm.), William Harrison (Councilor, Engineering Section), Michael B. Barber (Archaeology Section), Tom Sitz (Research Committee), Charles O'Neal (Microbiology Section), Hugo R. Seibel (Medical Sciences Sec. & Membership Comm.), Stewart Ware (Past-Past President), Elsa Q. Falls (Secretary)

The meeting was called to order at 1:37 p.m. by President Richard Brandt, and those present introduced themselves.

Approval of Council Minutes of March 2, 1991.

The minutes of March 2, 1991 were approved as distributed, as moved by Hugo Seibel and seconded by Ken Jacobs. Martha Roane asked for clarification, on behalf of Vera Remsburg, with regard to whether the travel fund approved in March by Council for the Science Museum Trustee covered lodging, meals, etc., as well as actual travel expenses, and those present agreed that such was the intention.

President's Report by Richard Brandt.

1. The President read a letter from UR Provost Zeddie Bowen inviting the Academy to hold its 1992 Annual Meeting at the University of Richmond and naming Dean Decker as Local Arrangements Chairman.

2. He announced that ballots submitted for new VAS officers were being counted by representatives of the Nominating Committee, and results would be available by the end of the Council Meeting.

3. A letter has been received from Governor Wilder congratulating VJAS on its fiftieth anniversary; it will be read at this evening's anniversary celebration.

4. The State Education Committee of the American Cancer Society has provided \$500 in prize money and certificates for outstanding VJAS papers related to cancer research.

5. He read a letter (attached) he wrote to Harold Bell thanking him for his years of excellent work in organizing and implementing the Visiting Scientists Program of the VAS.

6. He announced that Martha Roane has been made a Fellow of the Academy and will receive this award at the banquet tomorrow evening.

7. He read a letter (attached) from J. W. Jenkins of Sovran Bank asking that Dr. William L. Banks, Jr. be reappointed for another term as VAS representative on the Allocations Committee of the Thomas F. Jeffress and Kate Miller Jeffress

Memorial Trust and the Richard Gwathmey and Caroline T. Gwathmey Trust; Dr. Brandt has made this reappointment.

8. He has sent a letter (attached) to Section secretaries inviting them and new Section officers to the VAS President's luncheon on Thursday.

9. In the absence of Local Arrangements Chair Golde Holtzman, he reported that the Meeting was going well, as confirmed by Tom Sitz.

President-Elect's Report by Gerald Taylor.

Dr. Taylor's report (attached) included the following information:

1. Letters (attached) sent to approximately 1100 VAS members asking them to recruit new members resulted in less than a 3% response.

2. The Computer Science Section and the Archaeology Section are holding their first meetings. The Agriculture Section is holding a business meeting, and the Engineering Section is not meeting.

3. 395 papers will be presented at Senior Academy meeting this week, including some at three symposia: Biotechnology at Work, Geology in Virginia's Museums, and Land Use Patterns and Impacts on the Biota of Virginia.

4. He has asked sections to report attendance and turn in lists of old and new section officers (forms attached).

Secretary's Report by Elsa Falls.

The secretary requested that anyone presenting reports or making motions submit a copy to her in writing.

Treasurer's Report.

President Brandt announced that Treasurer Conway was absent due to her serving as a VJAS paper judge but that she would report at the Friday Council Meeting.

Executive Secretary-Treasurer's Report by Blanton Bruner.

He reported that the 1990 audit shows that the Academy is in good financial shape; the tax report was submitted on time. A check has been received from GMU for over \$18,000 as income from the 1990 meeting, but he is still awaiting their final report. This represents the largest income ever from an Annual Meeting; fees were raised for the 1990 meeting because of fears expressed by GMU Local Arrangements Committee members that expenses for the meeting might not be met.

Virginia Junior Academy of Science Report.

In the absence of Dean Decker, President Brandt reported that the VJAS Meeting is running smoothly. He reminded everyone of the VJAS fiftieth anniversary celebration this evening at 8 p.m., to be followed by a reception for VAS members at the Museum of Natural History.

Frank Leftwich reminded everyone that Dr. Decker is now beginning his last year as VJAS Director and a successor must be found. Gerald Taylor reported that a Search Committee, with Ertle Thompson as Chair, is already in place.

It was moved by Jim O'Brien and seconded by Hugo Seibel that Council pause in recognition of all of the voluntary contributions of time and energy by members of VJAS and their supporters which have led to the significant impact that VJAS has had on science in Virginia. The motion passed unanimously.

Virginia Journal of Science Report by Jim Martin, Editor.

He reported that he is over his budget of \$14,000 for the year. Issue four from last year was paid for this year and was an unusually large two-part issue, including

proceedings from a symposium on barrier islands and ten maps, costing \$10,000. This year's first issue cost \$5000, and there are two issues still to be published; the last issue will be small and cost approximately \$2000-\$3000. Some money will come in from sales of article reprints. The second issue for the year will consist of abstracts from the Annual Meeting and perhaps should be paid out of Meeting income. President Brandt indicated that VJS has been under budget the last couple of years, and Dr. Martin stated that was because articles he expected were not submitted on time.

It was moved by Frank Leftwich and seconded by Jim O'Brien that Blanton Bruner be authorized to appropriate whatever funds are necessary to fund VJS this year. The motion passed unanimously.

Blanton Bruner commented that if, in the future, funds for the publication of the VJS issue containing Annual Meeting proceedings are to come out of meeting income, this must be taken into consideration in setting meeting fees; generally the Annual Meeting does not make a large profit. Gerald Taylor suggested that the proceedings be listed as a line item expense for the Annual Meeting; Jim Martin indicated that issue would cost \$5000-\$6000.

Report of Director of Visiting Scientists Program by Harold Bell.

Preliminary work for the 1991-92 program is on schedule; he has heard from most colleges and universities, and the list of speakers will be sent to schools in the fall.

AAAS Report by Ertle Thompson, AAAS Representative.

Dr. Thompson's report (attached) expressed the concern of AAAS Council at the AAAS annual meeting in Washington, D.C. February 15-18, 1991, over the relatively low individual membership affiliations with Section Y - General Interest in Science and Engineering. Since representation to the AAAS Council is based on actual membership of the sections, and considering the fact that last year the Council approved an amendment permitting all AAAS members to become members of up to three sections, Dr. Thompson urged VAS members to affiliate with Section Y when they renew their memberships for 1991-92. He also reported that he was one of three representatives of the State Academies of Science elected to the rank of Fellow of the AAAS during the meeting of the AAAS Council on February 18.

Report of the Science Education Committee by Ertle Thompson.

He reported (report attached) that the major activity of the Science Education Committee during the past year was co-sponsoring of the Virginia State Department of Education Science Teachers' Meeting at the Omni Hotel, Charlottesville, Virginia, on November 9-10, 1990. Plans are now underway for the 29th Annual Virginia Science Teachers' Conference at the Omni International Hotel, Norfolk, Virginia, November 1-2, 1991.

Archives Report by Martha Roane.

She urged members to send archival material to Glen McMullen at the Newman Library, VPI, or give the materials to her.

Report of Constitution and By-Laws Committee by Frank Leftwich.

Dr. Leftwich requested that his report be postponed until later in the meeting, when ballot counters had returned. Jim Martin asked how new Sections become accredited and their names inserted into the Constitution; Dr. Leftwich replied that

Council can vote that such be done at the Friday meeting, after the new Sections have met on Thursday.

Report of Finance and Endowment Committee by the President for Arthur Burke.

At the Academy Conference on Thursday, the President will read a letter received from Arthur Burke indicating that the finances of the Academy are sound and it is solvent.

Fund Raising Committee. No report.

Long Range Planning Committee by Richard Brandt.

Sites for the Annual Meeting have been tentatively arranged through 1997.

Nominations Committee Report by the President for William Banks.

Dr. Banks has arranged for the ballots for new VAS officers to be counted.

Membership Committee Report by Hugo Seibel.

Copies of membership applications were sent to all Section Secretaries and pre-med advisors at state institutions, but only one response was received. Dr. Seibel will make use of a letter drafted by Carvel Blair to be sent to selected state agencies requesting that appropriate individuals within those agencies join VAS.

Research Committee Report by Tom Sitz.

John Hayden of the University of Richmond will receive the Horsley Award at the banquet on Thursday. Sitz received the largest number of proposals ever (21) for small project grants; the winners will be decided upon next week and will be published in *VJS* and *Virginia Scientists*. Gerald Taylor suggested sending an announcement of the Horsley Award winner to state institutions in order to generate more entries.

Science Advisory Committee. No report.

Trust Committee Report by Richard Brandt for Rae Carpenter.

Dr. Brandt indicated that Dr. Carpenter could not be present, but his report was distributed (attached). The current value of all fund holdings is \$171,253, up from \$157,696 in July 1990.

Report of Virginia Flora Committee by Martha Roane.

She stated that no time had been set aside for the Virginia Flora Committee to meet at this meeting; normally it meets at the end of the Botany Section papers on Thursday. Funds for this year were distributed equally between Michael Hill at Bridgewater and Miles Johnson at VCU. Donna Ware will be the new chair of this committee. Taxonomy on the grasses of Virginia was published in the last issue of *VJS* and is intended ultimately to be part of *Virginia Flora*.

Report of the Ad Hoc Committee on the Environment by Carvel Blair.

Dr. Blair reported on his Committee's ongoing work in reviewing the report of a field test of a raccoon rabies vaccine on Parramore Island in the Nature Conservancy's Eastern Shore Reserve. He needs the help of the Science Advisory Committee in finding persons to review the final report; the Committee also recommends that the final report be sent to appropriate state agencies for review.

Report of News and Publicity Committee by James O'Brien.

A report was distributed (attached) in which Dr. O'Brien urged VAS officers and honorees to publicize the Academy by requesting their institutional public relations offices to generate press releases. Copies of instructions were distributed (attached). He stated that Susan Trulove of Va Tech has done an outstanding job

in publicizing the Annual Meeting. He introduced Gregory Cook, Production Editor for Virginia Scientists, and announced that complimentary copies of the publication have been sent to the new Archaeology and Computer Science Sections. Susan Trulove needs immediately all information relative to honorees and VJAS winners. Dr. O'Brien needs as soon as possible the name of the person at University of Richmond who will serve as publicity contact for the 1992 Annual Meeting.

Psychology Section Report by James O'Brien.

Dr. O'Brien's report (attached) included the information that four awards will be given for outstanding VJAS papers with funding from the Virginia Psychological Foundation.

Medical Science Section Report by Hugo Seibel.

There are two full days of papers.

Microbiology Section Report by Charles O'Neal.

It will be proposed at the Section business meeting tomorrow that the name of this section be changed to Microbiology and Molecular Biology.

Archaeology Section Report by Michael Barber.

Fourteen papers will be presented.

There was a five minute recess declared by the President.

The President reported that the Nominating Committee has decided that election results will be made known privately to all candidates immediately following this meeting and then will be announced at the Academy Conference on Thursday.

Report of Past-President Michael Bass.

He urged Council members to be present at the VJAS Anniversary Celebration this evening.

Awards Committee Report by Jim Murray.

The Committee nominated the following for Honorary Life Membership in the Academy (report attached): Hubert J. Davis, first Director of the VJAS, and Martha L. Walsh, founding member of the VJAS Committee. The recommendation was unanimously approved.

Dr. Murray stated that the Committee has no active nominations at the moment. For persons wishing to make nominations, the deadline is October 1, for submission to the Executive Secretary who will forward them to the Awards Chair.

Engineering Section Report by William Harrison.

The Section will not meet here, but there should be good representation and a good number of papers at next year's meeting.

Astronomy-Math-Physics Section Report by Kenneth Jacobs.

Twenty-seven papers will be presented; there are no papers from several large state institutions.

Chemistry Section Report by George Mushrush.

A large number of papers will be presented due to active recruitment of such.

Environmental Science Section Report by Carvel Blair.

He announced a symposium on Friday: Land Use Patterns and Impacts on the Biota of Virginia.

Computer Science Section Report by Gregory Cook.

Seven papers will be presented at this first Section meeting; he is looking forward to a very active session by next year.

Gerald Taylor commended those involved in getting the new Sections, Computer Science and Archaeology, started.

Continuation of Report of Constitution and By-Laws Committee by Frank Leftwich.

The Committee presented the Bylaws change to Article III, Section 10. B., as proposed by Council at its Fall 1990 Meeting (report attached), so that the Nominations and Elections Committee nominate one candidate for each office instead of the current two. Notice of the proposed change was mailed to the VAS membership with the call for papers in January 1991.

The current status of Article 3 is as follows:

Article III: Duties of Standing Committees

Section 10. Nominations and Elections Committee shall:

B. Nominate a slate of two persons for each of the aforementioned offices and present report to Council for informational purposes.

The proposed change is as follows:

Delete the word "two" from Article III, Sec. 10, B and substitute the word "one".

The new sentence of Article III, Sec. 10, B shall read

"Nominate a slate of one person for each of the aforementioned offices and present report to Council for informational purposes".

It was moved by Hugo Seibel and seconded by Gerald Taylor that the motion be approved. Jim Murray, who proposed the change originally, explained that people who have come up for election several times and have not been elected have sometimes been lost to the Academy. As long as there is a way for persons to add names to the ballot if they so desire, the membership has not been disenfranchised. Stewart Ware indicated that he does not believe the present method is productive because six good people are used up and only three get elected. Gerald Taylor stated that having two nominees for each office results in recognition of six potential Academy leaders; those who are not elected can be used as committee chairs. He believes the process is more democratic. Frank Leftwich indicated that an additional name could be added to the ballot by the petitioning of twenty-five Academy members.

The motion was passed; there were 20 votes in favor, 2 opposed, and 1 abstention.

Announcements

The President reminded Council of upcoming events on the VAS Meeting Program. He indicated that the Negus Lecturer, Paul Knappenberger, will be leaving the Science Museum of Virginia to become President of the Adler Planetarium in Chicago. There are more persons attending the banquet than ever

before. He encouraged people to attend the Council Meeting on Friday, at which time a draft of a new directory will be available.

President Brandt adjourned the meeting at 3:23 p.m.

Respectfully submitted by:

Elsa Q. Falls, Secretary

Virginia Academy of Science

SUMMARY OF MOTIONS

COUNCIL MEETING, MAY 22, 1991

1. That the minutes of March 2, 1991 be approved as distributed. Moved by Hugo Seibel and seconded by Ken Jacobs. **Motion passed unanimously.**

2. That Council pause in recognition of all of the voluntary contributions of time and energy by members of VJAS and their supporters which have led to the significant impact that VJAS has had on science in Virginia. Moved by Jim O'Brien and seconded by Hugo Seibel. **Motion passed unanimously.**

3. That Blanton Bruner be authorized to appropriate whatever funds are necessary to fund VJS this year. Moved by Frank Leftwich and seconded by Jim O'Brien. **Motion passed unanimously.**

4. That the following be nominated for Honorary Life Membership in the Academy: Hubert J. Davis, first Director of VJAS, and Martha L. Walsh, founding member of the VJAS Committee. Moved by Jim Murray for the Awards Committee. **Motion passed unanimously.**

5. That Article III, Section 10. B., of the Bylaws be changed to read "Nominate a slate of one person for each of the aforementioned offices and present report to Council for informational purposes". Moved by Hugo Seibel and seconded by Gerald Taylor. **Motion passed, with 20 in favor, 2 opposed, and 1 abstention.**

VIRGINIA ACADEMY OF SCIENCE
CONFERENCE MINUTES

May 23, 1991 Virginia Tech

Virginia Academy of Science President Richard Brandt opened the 69th Academy Conference at 4:50 p.m.

He reported on a by-laws change (attached), which was approved at the Council Meeting on May 22, 1991, after the VAS membership had been provided with at least 30 days notice of the recommended change, as required. Article III, Section 10.B. now reads "Nominate a slate of one person for each of the aforementioned officers and present report to Council for informational purposes". He explained that the change was from two persons to one person being nominated by the Nominations and Elections Committee for each office: President-Elect, Secretary, and Treasurer.

President Brandt read the report (attached) from Arthur W. Burke, Jr., Chairman of the Finance and Endowment Committee, which indicated that the finances of the Academy are sound and that the Academy is solvent.

The newly-elected Academy officers were introduced and asked to stand: Treasurer, Thomas O. Sitz (Va Tech); Secretary, Carolyn M. Conway (VCU); and President-Elect, Golde I. Holtzman (Va Tech).

The President announced the names of the new or continuing Section officers (lists attached) and asked those present to stand.

Those present were reminded of the following:

1. The Sidney Negus Memorial Lecture will be given at 5:30 by Dr. Paul Knappenberger, Director of the Science Museum of Virginia.
2. The Va Tech President's Reception will be held at 7 p.m. and will be followed by the Academy Banquet at 8 p.m., for which a ticket is required.

President Brandt introduced Dean Decker as the Director of VJAS and commented on the excellent 50th Anniversary Celebration held on Wednesday. He announced that Dr. Decker will serve as Local Arrangements Chair for the May 1992 Annual Meeting, to be held at the University of Richmond.

Dr. Brandt adjourned the Academy Conference at 5:05 p.m.

Respectfully submitted by:

Elsa Q. Falls, Secretary

Virginia Academy of Science

CORRECTIONS SUBMITTED

In: Pagels, J. F. 1991. A High Elevation Record for the Least Shrew, *Cryptotis parva* (Say). Virginia Journal of Science, Vol 42, No. 3. pp 361-362.

The reported "occasional" occurrence of Fraser fir (*Abies fraseri*) on Whitetop Mountain resulted from an error in the transcription of field data. *Abies fraseri* was not encountered. Sentence two of paragraph three should read "...red spruce (*Picea rubens*, 90.8% of trees counted per ha), and widely scattered hardwoods, that included black locust (*Robinia pseudo-acacia*, 2.8%), American beech (*Fagus grandifolia*, 2.8%), yellow birch (*Betula lutea*, 2.2%), and black birch (*B. lenta*, 1.4%)."

Note from Virginia M. Dalton

-- to those owning or reading a copy of

Dept. of Game and Inland Fisheries, Commonwealth of VA. 1991. Virginia's Endangered Species: Proceedings of a Symposium. J. N. McDonald, managing ed. McDonald & Woodward Pub. Co., Blacksburg, VA. 672 pp.

I noticed an error in Recommendation 8 on p.576 concerning the acceptance of gates by *Plecotus*. I think it is major enough that I decided I should do something about it. Many people all over the country are involved in putting gates on bat caves. They might become very confused if they see the mistake in the Proceedings.

Correct the error by changing "intolerant" to "tolerant" in line 42 and deleting "also" in line 44.

The sentences should read:

Nursery colonies of *Plecotus townsendii* are tolerant of full gates (White and Seginak, 1987; C. W. Stihler, pers. comm.). Gray bat nursery colonies require partial gates (Tuttle, 1986).

MEMBERSHIP

Membership in the Academy is organized into sections representing various scientific disciplines as follows:

- | | |
|--|---|
| 1. Agriculture, Forestry and Aquaculture | 8. Geology |
| 2. Astronomy, Mathematics and Physics | 9. Medical Sciences |
| 3. Microbiology and Molecular Biology | 10. Psychology |
| 4. Biology | 11. Education |
| 5. Chemistry | 12. Statistics |
| 6. Materials Sciences | 13. Aeronautical and Aerospace Sciences |
| 7. Biomedical and General Engineering | 14. Botany |
| | 15. Environmental Science |
| | 16. Archaeology |
| | 17. Computer Science |

Annual Membership Dues - Includes subscription to Virginia Journal of Science

Student	\$ 10.00
Regular - Individual	25.00
Contributing - Individual	30.00
Sustaining - Individual	50.00
Sustaining - Institution	100.00
Business - Regular	100.00
Business - Contributing	300.00
Business - Sustaining	500.00
Life - Individual	300.00



VIRGINIA ACADEMY OF SCIENCE

APPLICATION FOR MEMBERSHIP

Date _____ Name (Please Print) _____

Phone (____) _____ E-mail _____ FAX(____) _____

Address _____

City _____ State _____ Zip _____

Institution or Business _____

Position — Title _____

Fields of Interest — Section No.(s) _____ First No. indicates major interest

Class of Membership Desired _____

Contacted by: _____

Make check payable to **VIRGINIA ACADEMY OF SCIENCE** and send to:
Department of Biology, University of Richmond, Richmond, VA 23173

Instructions to Authors

All manuscripts and correspondence about them should be addressed to the **Editor**. The Virginia Journal of Science welcomes for consideration original articles and short notes in the various disciplines of engineering and science. Cross-disciplinary papers dealing with advancements in science and technology and the impact of these on man and society are particularly welcome. Submission of an article implies that the article has not been published elsewhere while under consideration by the Journal.

Three complete copies of each manuscript and all figures are required. It is also suggested that authors include a 5.25 diskette in IBM[®] compatible format containing a text file (ASCII) of the manuscript. Original figures need not be sent at this time. *Authors should submit names of three potential reviewers.* All manuscripts must be double-spaced. The title, author's name, affiliation and address should be placed on a cover page. An abstract (*not to exceed 200 words*) summarizing the text, particularly the results and conclusions, is required. The text should follow the general format used by professional journals in the author's discipline. Literature cited in the text should follow the name-and-year: Fujishima and Honda (1972). In the Literature Cited section at the end of the article each reference should include author(s), year, title of article, title of journal (using standard abbreviations), volume number and first and last page of the article. For a book, include author(s), year, title, pages or number of pages, publisher and city of publication. Examples:

Fujishima, A. and Honda, K. 1972. Electrochemical Photolysis of Water at a Semiconductor Electrode. *Nature* 238: 37-38.

Spry, A. 1969. *Metamorphic Textures*. Pergamon Press, New York. 350 pp.

Each figure and table should be mentioned specifically in the text. All tables, figures and figure legends should be on a separate pages at the end of the text.

After revision and final acceptance of an article, the author will be required to furnish two error-free copies of the manuscript: 1) typed copy, single spaced, with tables and figure captions at the end of the document, and one set of original figures, each identified on the back by figure number and author's name; 2) a 5.25 diskette in an IBM compatible format containing the text file, tables and figure legends.

Authors will be allowed 15 printed pages (including figures) free, but payment of \$50 per page will be charged for the 16th and subsequent pages.

Virginia Academy of Science
Department of Biology
University of Richmond, Virginia 23173

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SUPPLIMENT TO VOLUME 42

1991-92 DIRECTORY
THE VIRGINIA ACADEMY OF SCIENCE



CONSTITUTION AND BYLAWS
FUTURE MEETING SITES
OFFICERS
EXECUTIVE COMMITTEE
MEMBERS OF COUNCIL
STANDING AND OTHER COMMITTEES
SECTIONS AND SECTION OFFICERS
PAST PRESIDENTS
ACADEMY AWARDS AND FELLOWS
HONORARY LIFE MEMBERS
MEMBERS

SEPTEMBER 1991

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TO MEMBERS AND FRIENDS OF THE VIRGINIA ACADEMY OF SCIENCE

The Virginia Academy of Science is a volunteer organization that is undergoing some exciting changes. Archaeologists and computer scientists have organized new sections, which were approved by the Academy Council at the 1991 Annual Meeting. The Agriculture Section has expanded to include forestry and the developing field of aquaculture. The Microbiology Section has changed its name to Microbiology and Molecular Biology to better reflect its members' areas of interest.

The Junior Academy is moving forward with its plans to expand and regionalize. Increasing interest and participation in science among our youth through the Junior Academy of Science is one of the most exciting challenges currently facing us.

The Virginia Scientist, the Academy's new newsletter, is bringing news of Academy activities and scientific problems of interest to Academy members. As editor James O'Brien stated, "The Virginia Academy of Science is taking bold new steps to meet the challenges confronting science, technology, and education in the Commonwealth."

At the 1992 Annual Meeting, which will be held at the University of Richmond, the Academy plans to change its Constitution to make the Committee on the Environment a Standing Committee. With the assistance of the Science Advisory Committee, the Committee on the Environment will address and seek scientific recommendations on vital environmental concerns of citizens of the Commonwealth. The Committee is developing its duties and enumerating its goals for presentation at the Fall meeting of Council. The minutes of Council, which are published in The Virginia Journal of Science, will keep us informed of these and future developments in the Academy.

I sincerely appreciate the efforts of all the officers and members of all Academy Sections in making the Annual Meeting a success and in preparing the lists of 1991-92 officers (that were delivered to me at the VAS President's luncheon at Virginia Tech). Without your help, the Directory--which identifies members and persons who are currently serving the Academy or the Virginia Junior Academy of Science--could not have been completed. With your help, the members of the Academy are developing opportunities for cooperation and fellowship among scientists of all disciplines and promoting scientific research and education throughout the State.

I encourage suggestions from members and others on ways in which the Academy can more effectively achieve its goals.

Sincerely,
Gerald R. Taylor, Jr.
President

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CONSTITUTION OF THE VIRGINIA ACADEMY OF SCIENCE¹

ARTICLE I: NAME

The name of this organization shall be the Virginia Academy of Science.

ARTICLE II: PURPOSE

The purpose of this organization shall be to establish and maintain in Virginia for scientific and educational purposes an association of persons and organizations interested in science and scientific research in all of its branches; to solicit financial and other support; to cooperate with educational institutions, industries, and state agencies in fostering an interest in scientific matters, in promoting scientific investigations and in spreading knowledge of the sciences; to provide a forum for the presentation and discussion of papers on scientific subjects and facilities for their publication; to provide opportunities for the cooperation and fellowship among its members; and generally, in doing these things, to benefit not only its own members, but to promote the civic, agricultural, academic, industrial and commercial welfare of the people of Virginia.

ARTICLE III: ORGANIZATION

Section 1. Membership

Membership in this organization shall be open to professional scientists of all branches of science and others who are interested in the purpose of the organization. Types of membership and dues for each shall be specified in Academy Bylaws. The membership, through the Academy Conference, provided by Section 2 of Article VIII, shall have ultimate authority over the affairs of this organization.

Section 2. Sections

The Academy shall be organized into sections according to the various scientific disciplines. A person may belong to one or more sections in accordance with his interests.

Section 3. Council

The governing body of this organization shall be the Academy Council. Its composition and responsibilities are specified in Article VII.

Section 4. Officers

The elected officers of this organization shall be a President, a President-elect, a Secretary, and a Treasurer. Duties of each shall be specified in Academy Bylaws.

Section 5.² Executive Committee

The elected officers, the immediate past president and the Director of the Junior Academy of Science shall comprise the Executive Committee of the Academy Council.

1 Approved by Academy at 1970 Annual Meeting. Subsequent changes indicated.

2 Amended May, 1986.

VIRGINIA ACADEMY OF SCIENCE DIRECTORY

Section 6.³ Standing Committees

The primary activities of this organization shall be implemented by Standing Committees as follows: The Research Committee, the Long Range Planning Committee, the Junior Academy of Science Committee, The Membership Committee, the Finance and Endowment Committee, the Trust Committee, the Publications Committee, the Awards Committee, the Fund Raising Committee, the Nominations and Elections Committee, the Virginia Flora Committee, the Science Advisory Committee, the Science Education Committee, and the Archives Committee, and the duties of the Standing Committees not specified hereafter, shall be as specified in the Academy Bylaws, and as may be further enumerated by Council from time to time.

ARTICLE IV: THE VIRGINIA JOURNAL OF SCIENCE

The Virginia Journal of Science shall be the official publication of the Virginia Academy of Science. All Academy members shall receive copies of this publication.

ARTICLE V: FELLOWS

From active membership, there shall be a body of scholars known as "Fellows of the Virginia Academy of Science" selected because of their contribution to science in one or more of the following ways: (a) outstanding scientific research, (b) inspirational teaching of science, (c) significant leadership in the Academy. Rules and procedures for selection of Fellows shall be specified in the Academy Bylaws.

ARTICLE VI: ACCREDITATION OF MEMBERSHIP

Membership of the Academy shall be accredited by the Secretary and the Treasurer. The membership list shall be published periodically according to types, as directed by Council.

ARTICLE VII: COMPOSITION AND RESPONSIBILITIES OF COUNCIL

Section 1.⁴ Council shall be composed of the President, the President-elect, the Secretary, the Treasurer, the three most recent Past Presidents and one member elected by each Section of the Academy. Members from the Sections shall be elected for three year terms on a rotational basis among the Sections, provided the initial term of a member from a newly established Section shall be specified by Council. In addition to the foregoing, the Chairmen of the Standing Committees, the Editor of the Virginia Journal of Science, and Visiting Scientists Program Director shall be members of Council. In event of vacancies, the President shall make interim appointments until the next election is held; provided however, vacancies of elected officers shall be filled as hereafter provided.

3 Amended May, 1986.

4 Amended May, 1975.

Section 2. Council shall meet each year preceding the annual meeting and at least once in the fall at a time and place designated by the President.

Section 3. Twelve members shall constitute a quorum for the transaction of business by Council.

Section 4. Council shall establish the policies of this organization and shall be responsible for the administration of all Academy funds.

Section 5. Council shall consider and recommend to the membership from time to time appropriate changes in the Constitution, and shall promulgate bylaws appropriate to the implementation of the Constitution.

Section 6. Council may establish appropriate administrative positions and employ such personnel as may be required. Terms of office, the duties and remuneration of such personnel shall be prescribed by Council.

Section 7. Through appropriate Bylaws, Council shall provide for the publication of the Virginia Journal of Science.

Section 8. The Executive Committee of Council shall be empowered to act for Council on an interim basis between meetings of Council and shall report to Council at its regular meetings. A meeting of Council may be called at any time upon concurrence of any four members of the Executive Committee.

ARTICLE VIII: MEETINGS AND BUSINESS

Section 1. The annual meeting of this organization shall be arranged in accordance with procedures to be established by Council in appropriate Academy Bylaws.

Section 2. All business requiring action by the membership shall be transacted at an Academy Conference, which shall be scheduled by Council during the annual meeting. A meeting of the Academy Conference may be called between Annual Meetings by concurrence of a majority of the members of Council; provided, however, that the membership shall be notified of such called meeting no less than 30 days prior to the date that such meeting is to be held. Forty accredited members shall constitute a quorum for the transaction of business by an Academy Conference.

Section 3. Each section shall annually arrange a program oriented to its area of scientific interest; provided, however, such programs shall be compatible with the purpose of the Academy and scheduled within the framework of the general meeting program of the Academy.

Section 4. The fiscal year of the Academy shall be from January 1 through December 31.

Section 5. The parliamentary procedure for all meetings of this organization shall be governed by Robert's Rules of Order Revised, and Council shall provide for a Parliamentarian.

VIRGINIA ACADEMY OF SCIENCE DIRECTORY

ARTICLE IX: ESTABLISHMENT OF SECTIONS

Section 1. Sections as defined in Article III with the approval of Council, may be organized by an accredited group of members. Each Section shall annually arrange a scientific program related to its area of interest.

Section 2. Such a section may become accredited and established after it has conducted one successful program at an annual meeting of the Academy.

Section 3. Any Constitution and Bylaws changes proposed by a Section must conform to the provisions of the Academy Constitution and Bylaws and shall be submitted to Council for review and approval prior to adoption by Section.

Section 4. Any Section which fails to conduct a program at two successive Academy annual meetings, may be dropped as a Section by action of Council; but, may be reinstated after subsequently conducting one successful program.

Section 5. When established, all Section names shall be enumerated in the Academy Bylaws, and thereby subject to provisions of Article XIII, Section 1.

ARTICLE X:⁵ ELECTION OF ACADEMY AND SECTION OFFICERS

Section 1. A "Nominations and Elections Committee" consisting of three recent Past Presidents, appointed by the President shall establish a slate of nominations for the positions of President-elect, Secretary and Treasurer and conduct an election for same in accordance with procedures specified by Academy Bylaws.

Section 2. Upon election, such officers shall serve one-year terms commencing at the annual meeting at which their election is announced and continuing until the next annual meeting; provided, however, the President-elect shall automatically ascend to the position of President at the end of this scheduled term of office at any prior time that the office of President may be vacated; however, such person shall not serve as President beyond the term that such person was originally scheduled to serve.

Section 3. All interim vacancies in Academy offices, other than president, occurring between annual Academy Conferences, shall be filled by Council from names of persons recommended by the Executive Committee. Persons so selected shall serve until the next Academy Conference.

Section 4. Each Section shall elect from their members:

- A. A Chairman, and a Secretary for one-year terms of office.
- B. A representative to Council in accordance with the provisions of Article VII.
- C. Other officers desired.

Section 5. Persons to fill vacancies in Section offices which occur between Annual Meetings, shall be designated by the Council Representative from that Section.

Section 6. All Elected officers shall serve without remuneration, but, at the discretion of Council, may be reimbursed for certain expenses incurred in conducting the business of the Academy.

ARTICLE XI: COMMITTEE STRUCTURE, APPOINTMENTS, TERMS, ETC.

Section 1. Except as provided otherwise, all Standing Committees shall be composed of 3 or more members, and the President shall designate Committee Chairmen, and appoint approximately one-third of the members of each Committee for terms of 3 years, and shall subsequently appoint members to fill unexpired terms that occur periodically.

Section 2. The Research Committee shall be composed of five (5) members, each appointed for a term of five (5) years. One new member shall be appointed each year by the President to replace the member whose term expires; unexpired terms shall also be filled by appointment by the President. The senior member of the Committee shall be Chairman.

Section 3.⁶ A Trust Committee, composed of three accredited members, shall be elected by Council, to serve for terms of three years on a rotational basis. The members of this Committee shall place in trust and supervise the management of Academy investments subject to annual review by Council. The Committee shall elect its own Chairman; provided, however, that should it be unable to do so, the President shall name the Chairman.

Section 4. The President and Council shall assign operational matters to appropriate Standing Committees; however, the President and/or Council may establish Special Committees as the need arises.

ARTICLE XII: JUNIOR ACADEMY OF SCIENCE

The Academy shall provide financial support, leadership, and supervision to a Junior Academy of Science. Effective working relationships shall be maintained with such Junior Academy of Science, through the Junior Academy of Science Committee.

ARTICLE XIII: BYLAWS AND AMENDMENTS

Section 1. Council shall promulgate appropriate Bylaws to implement or further clarify the Articles of this Constitution. The establishment or amendment of such Bylaws shall require an affirmative vote of a majority of the total membership of Council; provided, that all proposed Bylaws or amendments shall be distributed to the membership or published in an issue of the Virginia Journal of Science at least 30 days prior to action by Council.

VIRGINIA ACADEMY OF SCIENCE DIRECTORY

Section 2. This Constitution may be changed or amended, after the recommendation of a majority of the total membership of Council, by a two-thirds majority of an Academy Conference, provided all proposed changes shall be submitted to members of Council in writing no less than 15 days prior to the Council Meeting at which such proposals are to be considered and further provided that subsequent to approval by Council, all proposed amendments shall be published in the Virginia Journal of Science or distributed in writing to the membership no less than 25 days nor more than 50 days prior to presentation to an Academy Conference for adoption.

Section 3. All provisions of the Constitution and Bylaws in effect prior to the adoption of this Constitution, except the provisions of this Article, shall rule until new Bylaws are duly established in accordance with Section 1 of this Article.

ARTICLE XIV: ARTICLES OF INCORPORATION

The Articles of Incorporation of this organization (Charter) shall conform to the provisions of this Constitution and all amendments hereafter adopted. The Constitution and Bylaws Committee shall review and coordinate all necessary appropriate revisions of both documents and be responsible for the submission of all required reports to the State Corporation Commission and other governmental entities, annually or as otherwise required by law.

ARTICLE XV: DISSOLUTION OR LIQUIDATION

Section 1. In the event of dissolution or liquidation, all liabilities and obligations of the Academy shall be paid, satisfied and discharged.

Section 2. All assets remaining, including those received and held for scientific and educational purposes, shall be transferred to one or more societies or organizations engaged in activities substantially similar to those of the Academy; provided however, that no assets shall accrue to the benefit of any officer or member of the Academy.

BYLAWS OF VIRGINIA ACADEMY OF SCIENCE

ARTICLE I: TYPES OF MEMBERSHIP AND DUES

Section 1. There shall be eight types of members, regular, student, contributing, sustaining, life, patron, honorary life, and business.

Section 2. Dues of the first 4 types of members shall be as follows:

- (1) Regular members shall pay annual dues of twenty-five dollars (\$25.00).
- (2) Student members shall pay annual dues of ten dollars (\$10.00).
- (3) Contributing members shall be individuals who elect to pay annual dues of thirty dollars (\$30.00).
- (4) Sustaining members shall be individuals who elect to pay annual dues of fifty dollars (\$50.00) or more, and institutions which shall pay annual dues of one hundred dollars (\$100.00) or more.
- (5) To be in good standing the foregoing types of members must pay the specified dues by July 1.

Section 3. Life members shall be individuals who elect to pay to the Academy the sum of three hundred dollars (\$300.00) and thereby become exempt from further payment of dues.

Section 4. Patrons shall consist of those persons who have given to this organization the sum of one thousand dollars (\$1,000.00) or its equivalent in property. They shall have all the rights and privileges of regular members and shall be exempt from dues. An institution may also become a patron by meeting the above requirement. Its representative shall have all the rights and privileges of regular members.

Section 5. Honorary Life members shall consist of persons elected by the Council for long and distinguished service to science. They shall have all the rights and privileges of regular members and shall be exempt from dues. Previous active membership in this organization shall not be a requirement of eligibility.

Section 6. Business or industrial organizations, which elect to pay dues of one hundred dollars (\$100.00) annually, shall be Regular Business Members of the Academy, or may elect to:

- A. Pay annual dues of three hundred dollars (\$300.00) and be designated Contributing Business Members, or
- B. Pay annual dues of five hundred dollars (\$500.00) and be designated Sustaining Business Members.

ARTICLE II: DUTIES OF OFFICERS

Section 1. The President shall be the directing head of the Academy, shall preside at business meetings and general sessions of the organization, and shall appoint the members of the standing committees and of new committees authorized by the Council, in accordance with Article XI of the Constitution.

VIRGINIA ACADEMY OF SCIENCE DIRECTORY

Section 2. The President-elect shall assist the President as mutually agreed between them, shall serve as president in the latter's absence, and shall be responsible for coordinating the scientific programs of the Annual Meeting. He shall furnish the Academy at its Annual Conference with a list of committee memberships which he has set up to assist him during his year as President.

Section 3. The Secretary shall be responsible for keeping complete records of the Academy Conference and all meetings of the Council and Executive Committee.

Section 4. The Treasurer shall:

- A. Account for the income and disbursements through one Academy General Fund Account.
- B. Keep the membership lists of the Academy up-to-date.
- C. Upon request, supply the Secretary and others a list of all members in good standing.
- D. Receive and disburse all funds as approved by Council and directed by the President or Chairman of the Finance Committee.
- E. Submit to Council annually a written report of all receipts and disbursements, accompanied by a statement of audit from a certified public accountant.
- F. Furnish quarterly financial summaries to the Executive Committee, members of Council, and to members of the Finance Committee.
- G. Prepare annually and present to the Finance and Endowment Committee for review a proposed budget for Academy operations.

Section 5. The Treasurer and all administrative employees engaged in the receipt and disbursement of funds shall be adequately bonded.

Section 6. All officers shall be ex-officio members of all Academy Committees.

ARTICLE III: DUTIES OF STANDING COMMITTEES

Section 1. Research Committee shall:

- A. Review and award Academy Research Grants.
- B. Arrange for and present the J. Shelton Horsley Research Award.

Section 2. Long Range Planning Committee shall:

- A. Develop and advise Council on broad policies which will affect the Academy in the future.
- B. Solicit and study suggestions from the membership for the improvement of Academy activities.
- C. Investigate and evaluate proposed projects, publications and other factors that may relate to the long-range effectiveness of the Academy.
- D. Advise and consult with other Academy Committees relative to the foregoing and make recommendations to such committees concerning the effectiveness of their various activities.

Section 3. The Junior Academy of Science Committee shall:

- A. Provide Director for Junior Academy of Science.
- B. Coordinate activities of Junior Academy of Science including annual meeting.
- C. Prepare VJAS budget and submit to VAS Finance Committee by September 1.
- D. Prepare National Science Foundation proposal and submit to Executive Committee by October 1.
- E. Publish and distribute Proceedings of VJAS by October 1.
- F. Select two student representatives to attend American Junior Academy of Science.
- G. Solicit membership and participation in Junior Academy programs and projects.
- H. Select students for VAS and AAAS Honorary Membership Awards.
- I. Select recipient of Outstanding Science Teacher Award.
- J. Select recipient of VJAS Distinguished Service Award.
- K. Select students to present papers to Senior Academy Sections.
- L. Support and participate in all other programs and activities related to the work of VJAS
- M. Canvass colleges and universities for scholarships available to Science Talent Search Finalists.
- N. Forward list of available scholarships to all high schools sponsors that have requested applications for the Westinghouse Science Talent Search.
- O. Secure list of Virginia contestants from Science Clubs of America and establish a committee to select best 45 papers.
- P. Set up procedures for selecting the top 15 students and declare and announce them to be State Winners in the Virginia Science Talent Search, and all other contenders as runners-up.
- Q. Send names of winners and runners-up to colleges and universities in Virginia.

Section 4. Membership Committee shall:

- A. Make recommendations to Council, the Executive Committee and officers relative to policies on general membership.
- B. Promote membership growth and seek adequate representation from all scientific disciplines.
- C. Sponsor a Business Advisory Committee for the purpose of creating understanding between science and business, and to solicit business memberships to the Academy.

Section 5. Finance and Endowment Committee shall:

- A. Monitor and appraise income and expenditures, and make appropriate recommendations to the President, Executive Committee and Council.
- B. Estimate annually the anticipated income of the Academy and prepare a proposed budget for consideration by Council at its Fall meeting.
- C. Seek and encourage the establishment of endowments to the benefit of Academy activities.

VIRGINIA ACADEMY OF SCIENCE DIRECTORY

- D. At least one member of this Committee shall be a member of the Trust Committee.

Section 6. The Trust Committee shall:

- A. Place in trust and supervise the management of funds of the Academy designated by Council or otherwise for investment.
- B. Review all Academy investments annually and make appropriate adjustments subject to approval of Council.

Section 7. The Publications Committee shall:

- A. Develop and implement a continuing policy of review and evaluation of Academy publications.
- B. Present to Council annually through the Finance Committee the budgetary needs of the several Academy periodical publications.
- C. Make recommendations to Council relative to priority, publication, finance and distribution of non-recurring publications.
- D. Select and recommend to Council, as necessary; an Editor for the Virginia Journal of Science, and members of the editorial Board.
- E. Enlist the interest of all groups in worthwhile publications by the Academy.

Section 8. The Awards Committee shall:

- A. Select recipients of the Ivey F. Lewis Distinguished Service Award to be presented periodically to a member who has made significant contributions toward the activities of the Virginia Academy of Science.
- B. Select recipients of Special Awards periodically as directed by Council.
- C. Accept and submit to Council nominations for fellows in accordance to Article V of the Constitution and Article V of the Bylaws.

Section 9. The Fund Raising Committee shall from time to time at the direction of Council, plan, organize, and coordinate appropriate fund raising campaigns in support of Academy activities or projects contingent to the purposes of the Academy.

Section 10. Nominations and Elections Committee shall:

- A. Mail to the membership on or about January 1 each year a request for nominations of persons to fill the offices of President-elect, Secretary and Treasurer.
- B. Nominate a slate of one person⁷ for each of the aforementioned offices and present report to Council for informational purposes.
- C. Mail slate of nominees to members advising that names may be added to the slate by 25 members petitioning the committee on behalf of each name to be added.
- D. Prepare ballots with or without additional nominees as the case may be and mail to membership with registration and other information relative to annual meeting indicating deadline and address for return of ballot to committee.

- E. Count ballots and announce results at the Academy Conference. Should a tie vote result for any office, the Academy Conference shall vote on the nominees. In all cases, the nominee receiving the largest number of favorable votes shall be elected; provided, however, that only members in good standing may cast ballots.

Section 11.⁸ The Constitution and Bylaws Committee shall:

- A. Periodically receive and prepare drafts of all proposed changes in constitution as the occasion arises and present same to Council and membership for consideration as set forth in the constitution.
- B. Draft all bylaw changes as directed by Council and notify membership of such changes.
- C. Update articles of Incorporation (Charter) as required.
- D. Provide a Parliamentarian for all Council meetings and Academy Conferences.

Section 12.⁹ The Virginia Flora Committee shall:

- A. Promote the study of and publications of the flora and vegetation of Virginia.
- B. Sponsor symposia and conferences on the ecology, conservation, and preservation of the plant life of Virginia.
- C. Disseminate botanical information to all who are interested in the flora and ecology of Virginia.
- D. Serve as liaison between the Academy, government bodies, and institutions in matters pertaining to the plant life of Virginia.

Section 13. The Science Advisory Committee Shall:

- A. Provide scientific and technical information and advice requested by the Executive, Legislative, and other governmental bodies and agencies of the Commonwealth of Virginia.
- B. Serve as liaison for the collection and transfer of scientific information and/or advice solicited in (A).
- C. Collect and evaluate suggestions and opinions regarding topics of general public interest wherein science and technology may provide assistance, but where such assistance has not been requested. The Science Advisory Committee will make recommendations to the Academy, to the Executive Committee, and/or the Council of the Academy for review and approval. The Science Advisory Committee, upon direction of Council or Executive Committee, shall serve as a conduit for placement of such information before the appropriate Executive, Legislative, or other governmental body or agency.

8 Amended May, 1976.

9 Amended May, 1980.

VIRGINIA ACADEMY OF SCIENCE DIRECTORY

- D. Maintain an inventory of scientific interests and expertise of individuals within the Academy who are willing to serve in an advisory and/or consultant capacity to state government.
- E. At no time operate beyond constraints considered as proper conduct for a non-profit organization.
- F. Append all reports and recommendations with a statement as follows; "The Virginia Academy of Science assumes no legal or financial responsibility for the utilization or dispersal of scientific and technical data or advice provided by the science Advisory Committee, further, the Academy assumes no responsibility, financial or otherwise, to governmental agents or agencies, institutions, individuals or committee members pursuant to the conduct and activities of this committee.

Section 14.¹⁰ The Science Education Committee shall:

- A. Promote science education in the State of Virginia.
- B. Disseminate information about scientific matters and scientific topics of current interest.
- C. Respond to requests for assistance in matters dealing with education in the areas of mathematics and science, such as are embraced by the various Academy Sections and as directed by the President and Council of the Academy.
- D. Assist and cooperate with the Virginia State Department of Education in planning and conducting the annual State Science Teachers Conference, K-12. Delegated members of the Committee may hold and be responsible for funds generated by the activities of the State Science Teachers Conference, solely for the purpose of funding the Conference meetings. These funds shall remain separate from other funds of the Academy.

Section 15.¹¹ The Archives Committee shall address the business of collection, assembly, organization, cataloguing and storage of records, documents, awards and paraphernalia associated with the history and development of the Academy; and, in support of this:

- A. Secure an institutional repository for storage of the inactive records of the Academy.
- B. Secure the services of a qualified individual to establish and maintain the aforementioned records, as the official Archivist of the Academy; and such person shall be extended honorary membership in the Academy; and,
- C. Assist, and cooperate, with the Archivist in securing and screening of records and documents destined for permanent storage in the Archives.

¹⁰ Amended May, 1986.

¹¹ Amended May, 1986.

ARTICLE IV: VIRGINIA JOURNAL OF SCIENCE

Section 1. The Academy shall publish the Virginia Journal of Science quarterly.

Section 2. The staff of the Virginia Journal of Science shall be composed of:

- A. An editor recommended by the Publications Committee and appointed by Council for a three-year term.
- B. Such Associate Editors, Assistant Editors, or Editorial Board Members, appointed by the President, as are recommended by the Editor and the Publications Committee.
- C. Editors designated by individual Sections.

Section 3. All members of the Academy shall receive the Virginia Journal of Science.

Section 4. Subscriptions may be sold to non-members at a rate established by the Publications Committee and approved by Council.

ARTICLE V: RULES AND PROCEDURES FOR SELECTING FELLOWS

Section 1. A "Fellow" must be nominated by at least three members of the Academy. The Academy Council must approve each Fellow by a majority vote. It will be the usual procedure to announce new Fellows at an Annual Meeting.

Section 2. Nominations for Fellows with appropriate biographical information shall be sent directly to the Executive-Treasurer annually prior to October 1. All information received shall be forwarded to the Chairman of the Awards Committee for review and recommendations to Council prior to the subsequent Annual Meeting. All nominees not recommended by the Committee or not acted upon favorably by Council shall remain in consideration for one additional year.

Section 3. No more than twenty-five fellowships will be approved the first year. After the first year, no more than one-half of one percent of the total active membership shall be selected in any one year. The limiting number of Fellows shall not exceed five percent of the total active membership of the Academy. However, nothing in this section shall preclude the election of one fellow each year.

Section 4. All Fellows shall be presented with a suitably inscribed scroll.

Section 5. Appropriate announcement of new Fellows shall be made in the Virginia Journal of Science.

VIRGINIA ACADEMY OF SCIENCE DIRECTORY

ARTICLE VI:¹² THE DULY ORGANIZED SCIENTIFIC SECTIONS OF THE ACADEMY ARE:

- (1) Agriculture, Forestry, and Aquaculture
- (2) Astronomy, Mathematics, and Physics
- (3) Microbiology and Molecular Biology
- (4) Biology
- (5) Chemistry
- (6) Materials Science
- (7) Biomedical and General Engineering
- (8) Geology
- (9) Medical Sciences
- (10) Psychology
- (11) Education
- (12) Statistics
- (13) Aeronautical and Aerospace Sciences
- (14) Botany
- (15) Environmental Science
- (16) Archaeology
- (17) Computer Science

ARTICLE VII: OFFICIAL REPRESENTATION OF THE ACADEMY

Where official representation of the Academy is desirable the President or his designates shall represent the Academy. No officer or other Agency member shall receive reimbursement from Academy funds for such purposes, except that actual expenses of the Academy representatives in attending the annual meeting of the American Association for the Advancement of Science may be paid, subject to the funds provided in the budget by the Finance Committee.

ARTICLE VIII: MEETINGS AND BUSINESS

The annual meeting of this organization shall be held in the Spring of each year at a time and place selected by Council, which shall arrange for all appropriate sessions.

ARTICLE IX: EXECUTIVE SECRETARY-TREASURER

Section 1. The position of Executive Secretary-Treasurer is hereby established for the purpose of providing administrative assistance to the officers and committee chairmen.

Section 2. The Executive Committee shall select a qualified person for this position, specify his duties, and set appropriate remuneration which shall be approved by Council.

Section 3. The incumbent of this position shall serve at the pleasure of the Executive Committee, subject to review by Council.

12 At 1991 Annual Meeting of the Academy, the names of Section 1, Section 3, and Section 7 were changed. Addition of Section 16 and Section 17 were approved.

Section 4. The incumbent of this position shall attend all Council and Executive Committee Meetings and may participate in all deliberations as circumstances dictate, but, shall not have a vote in either body.

ARTICLE X: VISITING SCIENTISTS PROGRAM DIRECTOR

Section 1. The position of Visiting Scientists Program Director is hereby established for the purpose of implementing a Visiting Scientists Program in cooperation with the State Board of Education.

Section 2. The Executive Committee upon recommendation of the President shall select a qualified person for this position and approve guidelines for the conduct of the program.

Section 3. The incumbent of this position shall serve at the pleasure of the Executive Committee, subject to review by Council.

**VIRGINIA ACADEMY OF SCIENCE
DIRECTORY**

**FUTURE MEETINGS &
LOCAL ARRANGEMENT CHAIRS**

1992 Meeting

University of Richmond
Richmond, VA 23173
May 19-22, 1992

R. Dean Decker
Chair of Local Arrangements

1993 Meeting

Old Dominion University
Norfolk, VA 23529
May 1993

William Check
Chair of Local Arrangements

1994 Meeting

James Madison University
Harrisonburg, VA 22807
May 1994

Kent Moore and Diane Spreser
Co-Chairs of Local Arrangements

1995 Meeting

Virginia Military Institute &
Washington And Lee University
Lexington, VA 24450
May 21-24, 1995

Rae Carpenter
Chair of Local Arrangements

PRESIDENT

Gerald R. Taylor, Jr.
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703-568-6328 (O)
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VIRGINIA ACADEMY OF SCIENCE DIRECTORY

ACADEMY COUNCIL

The governing body of the Virginia Academy of Science is the Academy Council. The composition and responsibilities of Council are specified in Article VII of the Constitution of The Academy. For 1991-92, Academy Council consist of the following:

- I. Executive Committee
 - President
 - President-Elect
 - Secretary
 - Treasurer
 - Immediate Past President
 - Director of the Junior Academy of Science
- II. Three Most Recent Past Presidents
- III. Section Representatives (One Representative per Section; 17 Sections)
- IV. Chairs of Standing Committees
- V. Editor of Virginia Journal of Science
- VI. Visiting Scientists Program Director
- VII. Non-voting Members of Council
 - Chairs of Other Committees
 - AAAS Representative
 - Science Museum of Virginia Trustee
 - Editor of The Virginia Scientist
 - Chair of Local Arrangements Committee
 - Executive Secretary-Treasurer

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 703-972-2453 (H)

Stewart A. Ware, Past-Past-Past-President
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DIRECTORY****EDITOR AND BUSINESS MANAGER
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DIRECTOR OF THE VISITING SCIENTISTS PROGRAM

Harold M. Bell

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703-552-2923 (H)

SECTION REPRESENTATIVES TO COUNCIL

(Representatives hold 3 year terms, elected on a rotational basis in accordance with provisions of Article VII of VAS Constitution,)

AERONAUTICAL AND AEROSPACE SECTION

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BIOLOGY SECTION

Rosemary Barra (1992)
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BIOMEDICAL AND GENERAL ENGINEERING SECTION

(Co-representatives during revitalization.)

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MICROBIOLOGY AND MOLECULAR BIOLOGY SECTION

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STATISTICS SECTION

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EDUCATION SECTION

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ACADEMY COUNCIL
Chairs of Standing Committees

25

CHAIRS OF STANDING COMMITTEES

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ACADEMY COUNCIL
Chairs of Standing Committees

27

RESEARCH COMMITTEE

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703-231-6315 (Leave message)

SCIENCE ADVISORY COMMITTEE

William L. Dewey, Co-Chair (1993) Research and Graduate Affairs MCV/VCU, Box 568 Richmond, VA 23298 804-786-0732 (O)	Richard B. Brandt, Co-Chair (1994) Department of Biochemistry MCV/VCU, Box 614 Richmond, VA 23298 804-786-0104 (O) 804-355-0436 (H)
--	--

SCIENCE EDUCATION COMMITTEE

Donald Mikulecky, Co-Chair (1994) Department of Physiology MCV/VCU, Box 551 Richmond, VA 23298 804-225-4500	Julia Cothron, Co-chair (1994) Director, Mathematics & Science Center 2401 Hartman Street Richmond VA 23223 804-788-4454
---	--

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DIRECTORY**

**OTHER COMMITTEE CHAIRS AND
NON-VOTING MEMBERS**

COMMITTEE ON THE ENVIRONMENT

Carvel Blair, Chair
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COMMITTEE ON POLICIES AND BUSINESS REVIEW

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SEARCH COMMITTEE: INTERIM DIRECTOR OF VJAS

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**VAS-FUTURES COMMITTEE
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APPOINTED FOR 1991-96 BY COUNCIL)**

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**1992 LOCAL ARRANGEMENTS COMMITTEE
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VIRGINIA ACADEMY OF SCIENCE DIRECTORY

(The VAS Constitution provides that with the exception of the Research Committee, the President shall designate Standing Committee Chairs and appoint approximately one-third of the members of each Committee for terms of 3 years. The date in brackets beside each name is the year the individual committee member rotates off the committee. Duties of Standing Committees are listed in ARTICLE III of the Academy Bylaws.)

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